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HUMAN FACTORS ENGINEERING SEMINAR

U.S. Army:

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PREFACE

This seminar series on human factors engineering has been arranged with the kind support of Dr. Lynn Baker, U.S. Army Chief Psychologist and Chairman of the Army Human Factors Engineering Committee. His assistance is gratefully acknowledged.

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SCHEDULE OF LECTURES

This document consists of course outline material for a human factors engineering (HFE) seminar. Among the subjects included are:

Introduction to Course
Dr. Jesse Orlansky

Scope of Human Factors Engineering;
Mr. Joseph G. Wohl

Design for Maintainability
Mr. Joseph G. Wohl

Workplace Layout and Body Size;
Mr. Robert T. Eckenrode

Effect of Environment on Performance;
Mr. Robert T. Eckenrode

Man-Machine Dynamics;
Dr. Jerome H. Ely

Man's Output Characteristics and Control Design;
Dr. Jerome H. Ely

Perception and Display Design; →(cont on p iv)
Dr. Jesse Orlansky

(cont fr p iii)

Training Considerations Affecting Design;
Dr. Jesse Orlansky

Human Decision Making; and
Dr. Martin A. Tolcott

Experimental Methods for Design and Evaluation,
Dr. Martin A. Tolcott

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PART I. LECTURE OUTLINES

SCOPE OF HUMAN FACTORS ENGINEERING

A. Brief Introduction

B. What is Human Factors Engineering?

1. It is not the engineering of humans.

2. Fitting the machine to man--engineering for human use.

3. Analysis and synthesis of man-machine systems.

4. Appreciating the hyphen.

C. Scope of Human Factors Engineering

1. Scope of man-machine systems.

   a. Simple man-machine systems.

   b. Complex man-machine systems.

2. Depth of analysis and application.

   a. Simple man-machine interactions.

      1) Color and lighting

      2) Knob-and-dial (dialectical knobulism)

      3) Panel and workspace layout

   b. Complex man-machine interactions.

      1) Man as an element in a servo or continuous control system

      2) Man as a decision-making element at a strategy level

D. Techniques of Human Factors Engineering

1. System operational description. Concept and use of "models."

2. Criterion of system performance.

3. Logical or mathematical analysis of operational description with respect to criterion of performance.

4. Synthesis. Modifying and optimizing the operational description.

   a. Division of authority, responsibility and duties between man and machine.

   b. Number of men.

   c. Duties of each.

5. Design. Selection, design and layout of components to optimize important man-machine interactions.

6. Evaluation.

   a. Checking actual system *performance* against original criteria.

   b. Checking performance in a field environment.

   c. Recommending design modifications for operational equipment.

E. Selected Examples

1. Coffee for breakfast.

2. Landing a remote-controlled B-47.

3. Maintenance, or "move to the rear of the equipment, please!"

4. The proper periscope problem.

F. Use of Available Literature

G. Identifying Areas of Potential Payoff for Human Factors Engineering

DESIGN FOR MAINTAINABILITY

A. Introduction

1. Definition: Promoting the ability to maintain equipment through proper design.

2. Scope and importance.

   a. "Promoting" implies taking an active part in changing something for the better.

   b. "Ability to maintain" depends upon many iceberg-like factors.

   c. "Proper design" refers not solely to equipment design.

3. Purpose of this lecture.

   a. To map out the roads to maintainability.

   b. To identify and discuss the signposts along each road.

   c. To define the destination more clearly.

   d. To develop an appreciation for the scenery: what the trip means for various groups and how it affects them.

B. The Maintenance Problem: Its Scope and Importance

Examples of what kinds of factors affect "ability to maintain."

C. Who Gets Involved in Maintainability: The Maintenance "System"

D. Developing the Maintenance Plan

1. Organization for maintenance.

2. Definition and description of processes involved.

3. Identification of significant decision points.

4. Identification of important system variables.

5. Analysis.

6. Trade-offs.

7. Taking costs into account.

8. Taking other variables into account (e.g., spare parts, overhaul).

E. Designing the Equipment for Maintainability

1. The relative importance of repair time depends upon the interrelationship of system parameters.

2. Ways of measuring repair time.

   a. Random failures and repairs.

   b. Non-random failures and repairs.

   c. Probability distribution of repair time.

   d. Experimental approach.

   e. Taking the measures.

   f. Interpreting the measures in terms of equipment design features.

3. Ways of reducing repair time.

   a. The repair process: trouble prevention, detection, localization, repair or replacement, and checkout. Significance of localization and repair or replacement stages.

   b. Trouble prevention: preventive maintenance. Uselessness if failures are random. Usefulness otherwise.

   c. Reducing detection time.

d. Reducing localization time: experimental results.

e. Reducing repair or replacement time.

f. Reducing checkout time.

g. Maintainability design practice checklist.

F. <u>Promoting Maintainability</u>

1. Specification of maintainability: the key problem.

   a. How much maintainability? At what price?

   b. Maintainability minimum is automatically specified by the setting of other system variables.

2. Measurement of maintainability: the repair process again.

3. How to reach the desired minimum level at least cost. In any individual instance, identify and concentrate on reducing those stages of the repair process which promise the greatest payoff for the least investment.

4. Motivating yourself and your associates: the vast potential payoff.

5. Getting the contractor to "do" it or the procuring agency to "buy" it. Maintainability specifications and clauses in development and production contracts.

WORKPLACE LAYOUT AND BODY SIZE

A. <u>Basic Considerations</u>

1. Human body size, movements and forces which can be exerted.

2. Requirements of the task.

3. Equipment and operational constraints.

B. <u>Body Measurements</u>

1. Development of data.

   a. Selection of population samples.

   b. Distribution of measurements.

   c. Some characteristics of the distribution.

      1) *Central tendency:* mean, median.

      2) Variability: standard deviation, quartile deviation, percentile deviation, RMS error, average deviation, probable error, total range.

2. Sources of data: handbooks and reports.

3. Use of data.

   a. Using the average.

   b. Consideration of variability.

C. <u>Application of Data to Workplace Design: The Marriage of Man and Equipment</u>

1. Over-all workspace layout.

   a. Available space.

b. Nature of human tasks: supervision, operation, communication, calibration, maintenance, training, housekeeping.

c. Individual vs. group performance.

d. Traffic problems and emergency considerations.

e. Illumination and other environmental control.

f. Importance of models.

2. Equipment form factors.

a. Available space.

b. Nature of human tasks: operation, maintenance, training.

c. Single vs. multi-man operation.

d. Stand-up vs. sit-down operation.

e. Importance of static mock-ups.

3. Layout of panels.

a. Functional use.

b. Sequence of operation.

c. Primacy or importance.

d. Frequency of use.

e. Optimal location for use.

f. Criticality of use.

g. Effects on system.

h. Inadvertence of operation.

i. Importance of operating mock-ups.

4. Design of seating.

a. Available space.

b. Operator tasks.

c. Emergency considerations.

d. Body support considerations: back, seat, legs, arms.

EFFECT OF ENVIRONMENT ON PERFORMANCE

A. Introduction

It is convenient to think of the environment of man as composed of two parts: things and people. Because man interacts in different ways with things and people, we will break this discussion into two parts: *the physical environment* and the social environment.

B. The Physical Environment

1. In considering man in relation to his physical environment, it is useful to think in physical terms and conceive of a man as having three parts:

   a. A series of detectors sensitive to various forms of external physical energy.

   b. A series of transducers which convert this external energy into electrochemical energy.

   c. A central nervous system which receives the electrochemical energy from the transducers and selectively compares it with particular patterns of previous impressions in the memory.

2. Human detectors respond to changes in level of specific forms of energy, with specific frequency ranges, and specific minimum rates of change.

3. Three criteria are normally used in determining the "goodness" of man's environment.

   a. Survival, health and safety, measured by:

      1) Number of deaths or death rate.

      2) Accidents, classified by frequency, degree of disability, productive days lost, property damage, etc.

      3) Illness, classified by frequency, productive days lost, etc.

b. Performance, measured by:

1) Speed of performance.

2) Accuracy or precision of performance.

3) Rate of performing.

4) Energy expenditures in performance, etc.

c. Feelings, attitudes, comfort, etc., which can be either positive or negative.

1) Positive--work satisfaction, perseverence in performing, high morale, etc.

2) Negative--discomfort, fatigue, fear, hostility, monotony, work dissatisfaction, etc.

Some measures of these criteria are:

a) Frequency and types of complaints.

b) Attitude surveys.

c) Certain psychological tests.

d) Re-enlistment rate.

e) Frequency with which personnel get in off-duty trouble, etc.

4. All of these criteria can be stated in terms of cost. The problem is ultimately to balance the cost of improving the working environment with the cost of continued operation under the present environment, with due consideration for:

a. Direct cost of making changes.

b. Changes in over-all system performance.

c. Changes in personnel turnover, with consequent changes in training costs.

d. Changes in accident costs, etc.

5. In looking at the effects of changes in environmental factors we will be concerned primarily with operator performance in various types of tasks, although in passing we will mention the criteria of safety and comfort where appropriate. The environmental factors with which we will be concerned here are:

a. Mechanical vibration and acceleration.

b. Noise and blast.

c. Heat: radiation, conduction, convection.

d. Air condition.

e. Light.

f. Electricity and electromagnetic radiation.

g. Atomic radiation, X-rays, cosmic rays.

6. Combinations of variables and criteria. Generally, the criteria against which "goodness" of a working environment is measured fall along a continuum into three classes. At the more severe end of this continuum are survival, health, and safety; at the mild end are personal comfort and feelings; and between the two are criteria against which working performance is measured. Thus, the first effort should be to control the environment so that the variables fall into the comfort zone. Where this is impossible or impractical the effort should be directed towards keeping them in the adequate performance zone. At the very least it is important to control the variables in such a way that they are retained within values which will prevent permanent damage to personnel.

The steps in following this plan for any particular task are as follows:

a. Identify the ultimate criterion, usually a cost, for the task and the specific environmental factors which must be controlled to insure personnel comfort, adequate performance, and safety.

   1) What are the primary missions, purposes or functions of the unit under consideration?

   2) What are the secondary needs?

b. Determine the specific ranges of each factor which satisfy the three criteria.

c. Determine the equipment necessary to retain the factors within these ranges and make whatever compromises may be necessary to optimize such equipment in terms of the ultimate criterion.

d. From this determination develop preliminary requirements for equipment to be supplied.

e. Where possible, check out the task using typical operators operating under the selected ranges of environmental factors and make any adjustments which will improve performance as measured against the ultimate criterion.

f. Develop final requirements or specifications.

g. When the actual equipment is available, check it out under the expected range of field conditions, using as operators the eventual users, and make any final modifications which will further enhance system performance.

C. The Social Environment

1. Introductory remarks.

a. A difficulty in communication: We will talk about the social environment while we are, at the same time, subject to it.

b. The Hawthorne study: A classic research in human engineering and systems analysis.

c. The HAWK Launcher selection decision: A military example.

2. Goals of work groups.

a. Goals of individuals in work groups.

b. Over-all goals of the groups.

c. Importance of fusing individual and group goals.

3. Characteristics of the individual as a member of a work group.

   a. Personality: Attitudes, beliefs, experience. Visual detection experiment.

   b. Personal needs for economic reward, recognition, achievement, satisfying social interaction with other members of the group and people outside the group.

4. Role of the social environment in "traditional" man-machine systems. Conventional systems tend to be organized so that the man-machine activity meets the demands of the social environment and the social environment encourages appropriate behavior in the man-machine system.

5. Role of the social environment in highly automated and advanced weapons sytems.

   These new systems tend to make demands in conflict with those of the social environment, to the likely detriment of system performance.

   a. Infrequent involvement of men and machines; the monitoring function.

   b. Isolation of operating members from each other.

   c. Ambiguity of system utility and meaning.

6. Designing an individual job in a group.

   a. Independence: the degree to which a job can be done by one man alone.

   b. Interaction: the degree to which one job depends on other jobs.

   c. Job complexity and personal interest as affected by the job's independence-interaction characteristics.

   d. Principles for designing group structure.

7. Characteristics of a work group.

   a. Work plan.

   b. Communications.

   c. Authority.

   d. Continuity.

   e. Identification.

   f. Reward and punishment.

8. Procedures for designing work groups for systems.

   a. Determine system goals.

   b. Determine goals of individual groups.

   c. Examine factors affecting individual group functioning.

   d. Determine space requirements for each group.

   e. Determine optimum location for each group relative to other groups.

MAN-MACHINE DYNAMICS

A. Systems Approach to Design

1. Various levels of man-machine systems

   a. Range from simple physiological systems to complex macrosystems.

   b. Historically human factors concerned first with simple, now with one-man-and-one-machine, future with teams of men.

2. First design decision: Determine tasks to be done by men and by machines.

   a. Ultimate division of duties based upon system optimization.

   b. Need information about advantages and limitations of both men and machines.

B. Functions of Men and Machines

1. Limitations of men

   a. Accuracy

      1) Susceptible to constant errors

      2) Susceptible to variable errors

   b. Speed

      1) Reception time

      2) Decision time

      3) Movement time

      4) Refractory periods

c. Force

1) Body members being used

2) Fatigue

d. Computing (conceptual and perceptual)

1) Slow and inaccurate

2) Perceptually limited to single integrations and differentiations

e. Social interactions

1) Disturbed by isolation

2) Special effects of sensory deprivation

2. General characteristics of men

a. Decision-making

1) Optimum strategy not always used

2) Perseveration

3) Can be developed into valuable skill

b. Information input rate

1) Susceptible to overloading

2) Stress and boredom affect performance

c. Trainability

1) Individual differences

2) Different tasks require different skills

3) Fallacy of simplifying manpower requirements through automation

3. Advantages of men

   a. Detection

      1) Wide range of signals

      2) Weak signals

   b. Perception

      1) Complex situations

      2) Constancy

      3) Signals through noise

   c. Flexibility

      1) Rapid shifts of attention

      2) Alternate modes of operation

   d. Judgment

      1) Inductive reasoning

      2) Incidental intelligence

      3) Low probability events

      4) Hunches

   e. Reliability

      1) General performance under adverse conditions

      2) Performance when parts are "out of order"

      3) Performance when highly motivated

4. Limitations of machines

   a. Maintenance

   b. Monitoring

   c. Decision-making

5. Advantages of machines

a. Speed

b. Accuracy

c. Short-term memory

d. Simultaneous activities

e. Complex problems

f. Repetitive tasks

C. <u>Presentation of Discrete Signals to an Operator</u>

1. Overloading

a. Factors affecting performance

1) Frequency

2) Bunching

3) Complexity of decisions

b. Operator performance when overloaded

1) Lags

2) Omissions

3) Frustrations

c. Recommendations

1) Anticipatory information

2) Restriction of input rate

2. Pacing

a. Types

1) Forced-pacing

2) Self-pacing

b. Effects of operator variability

c. Recommended type: Self-pacing

3. Vigilance

a. Human performance in watchkeeping tasks

1) General poor level

2) Degradation with time

b. Factors affecting performance

1) Signal frequency

2) Signal intensity

3) Signal duration

4) Signal repetition

5) Search area

6) Task precision

c. Recommendations

1) Job rotation

2) Rest periods

3) Length of watch period

4) Working environment

5) Social environment

D. <u>Presentation of Continuous Signals to an Operator</u>

1. Continuous control tasks

   a. Nature of tasks

      1) Tracking

      2) Vehicular control

   b. Description of tasks

      1) Identification of important parameters

      2) Development of mathematical models

2. Factors affecting operator performance

   a. Input characteristics

      1) Signal frequency

      2) Signal amplitude

      3) Signal complexity

      4) Time-history of signals

   b. Machine dynamics

      1) Lags

      2) Sensitivities

      3) Integrations

3. Recommendations

   a. Control design (covered in another talk)

   b. Display design

      1) Pursuit vs. compensatory

      2) "Integrated" vs. discrete

      3) Quickened vs. unquickened

      4) Predictor

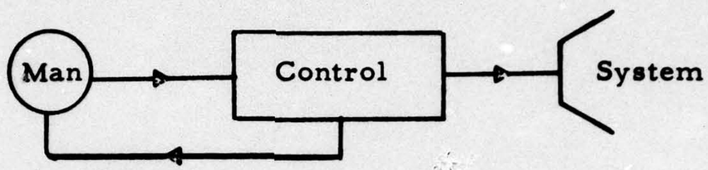
MAN'S OUTPUT CHARACTERISTICS AND CONTROL DESIGN

A. Introduction

1. Involves human output.

   a. Aids operator in implementing his decisions.

   b. Involves following relationships:



2. Major output forms.

   a. Speech.

   b. Manipulation of controls.

3. Important human factors problems.

   a. Selection.

   b. Design.

   c. Location (part of Workplace Layout)

B. Control Selection

1. "Goodness" of control.

   a. No predetermined general values.

   b. Goodness a function of system requirements.

   c. Some general rules applicable.

2. General rules for selection.

   a. Division of work among limbs.

1) Hands for precision

2) Hands for speed

3) Feet for strength

4) "Least effort" principle not always applicable

b. Compatibility with movement of associated display and/or vehicle

1) Affects linear vs. rotary displays

2) Is affected by workplace layout

c. Discrete adjustment vs. continuous adjustment controls

1) Discrete adjustment controls transmit less information

2) Discrete adjustment controls require only gross movements

d. Effects of working environment

1) Special clothing

2) Restricted space

e. Ease of identification

1) Important when there are several controls

2) Important when operation is periodic

3) Standardized locations most effective

4) Primary and emergency controls identifiable visually and nonvisually

5) Identification should not interfere with manipulation

C. Control Design: General

1. Purposes

a. Transmit energy

1) Historically most important

2) Machine aids have reduced importance

b. Transmit information

1) Historically sent forward

2) Now recognize need for "feedback"

2. Most important design considerations in transmitting information

a. Control-display ratio (C/D ratio)

b. Physical constants

c. Identification

d. Compatibility

D. Control Design: Control-display (C/D) Ratio

1. Definitions

a. Position control: Position of control directly affects position of controlled object.

$X_o = K_1 X_i$ when $X_i = f(t)$

where X_o: Position of controlled object

X_1: Position of control

$1/K_1$: C/D ratio

b. Rate control: Position of control directly affects rate of movement of controlled object.

$$X_o = K_2 \int_0^{+} X_i \, dt \qquad \text{when } X_i = f(t)$$

where K_2: Gain

c. Rate-aided control: Position of the control directly affects both position and rate of movement of the controlled object.

$$X_o = K_1 X_i + K_2 \int_0^{+} X_i \, dt \qquad \text{when } X_i = F(t)$$

where K_1 / K_2: Aided tracking constant

2. Importance in control design

a. Primarily in position control

b. Direct saving in adjustment time

3. Factors affecting ratio

a. Tolerance

b. Viewing distance

c. Machine dynamics

E. <u>Control Design: Physical Constants</u>

1. Importance

a. Aids operator to make desired control movement

b. Provides feedback

1) Most needed when visual feedback inadequate

2) Type of feedback depends upon choice of constants

2. General model:

$$F(t) = Kx + F\,dx/dt + Md^2x/dt^2 + C$$

where $F(t)$: Force being applied by operator

x: Control position

a. $\underline{Kx}$: Spring-loading - provides information about control position

b. $\underline{F\,dx/dt}$: Viscous damping - provides information about control velocity

c. $\underline{Md^2x/dt^2}$: Inertia - provides information about control acceleration

d. $\underline{C}$: Coulomb friction (independent of force being applied)

3. General uses of resistance

a. Precision of control movement

b. Speed of adjustment by reducing overshooting

c. Reduction of fatigue by permitting limb to rest on control

d. Elimination of accidental activation

F. Control Design: Identification

1. Importance

a. For training

b. When controls used infrequently

2. General design considerations

a. Often the outcome of good design

b. Danger of cluttering

3. Most common methods of identification

a. Location

1) Usually most effective

2) Often only kind required

b. Shape

1) Should provide tactual discrimination

2) Should give visual information

c. Size

1) Relative discriminations give more categories

2) For absolute discriminations maximum of three categories

d. Color

1) Requires direct vision

2) Requires proper lighting

3) Limited by terminology

e. Labeling

1) Important for training

2) Discussed elsewhere

f. Mode-of-operation

1) Provides kinesthetic cues

2) Useful only after control activated

G. Control Design: Compatibility

1. Importance

   a. Prevents reversal errors

   b. Critical conditions

      1) Delayed feedback

      2) Discontinuous operation

      3) Number of controls

2. Movement relations must consider

   a. Control

   b. Display

   c. Equipment component

   d. Total system

3. Proper relationships determined by

   a. Design practices (standardization)

   b. Habit patterns (population stereotypes)

PERCEPTION AND DISPLAY DESIGN

A. <u>Sensory Mechanisms that Influence the Design of Displays</u>

1. Sensation--the response to physical stimulation

   threshold

   relation between physical stimulation and sensation.

2. The senses currently useful for display of information:

   a. Vision.

   b. Hearing.

   c. Touch.

   d. Kinesthesis.

3. The characteristics of the eye which must be considered in designing a display.

   a. Light sensitivity.

      1) Illumination--scotopic versus photopic levels.

      2) Acuity as a function of illumination and contrast.

      3) Signal intensity and detectability.

   b. Color sensitivity.

      1) The visible spectrum.

      2) Effect of brightness.

      3) Color mixture.

c. Intermittent stimulation--flicker.

1) Flashing signals.

2) Flash rates.

3) Duty cycle, on-off period.

d. After images.

e. Two eyes versus one.

4. The ear as a data receiver--benefits and limitations.

a. Range of sensitivity.

1) Intensity.

2) Frequency.

3) Quality.

b. Useful parameters for display.

1) An example--Flybar.

a) Intensity versus frequency.

b) Intermittent signal.

2) Masking, enhancement, etc.

c. Two ears versus one.

1) Dichotic sensation--localization.

2) Sonobuoy localization a problem.

5. Touch provides more and better data than we realize.

a. Relative speed of response.

b. Kinds of feedback currently used.

c. Possibilities and problems for future consideration.

6. Kinesthetic, somosthetic, and vestibular sensations.

Always present--reliability may be questionable.

B. Perception--The Organization of Sensation

1. The role of past experience and training.

   a. Early learning and formal training.

   b. Transfer and interference.

   c. Influence of needs on what we see.

2. The types of organization.

   a. Figure and ground.

   b. Similarity.

   c. Continuity.

   d. Nearness and similarity.

   e. Perspective.

   f. Superposition.

   g. Texture.

   h. Motion parallax.

   i. Constancy of experience.

C. Description of a Display

1. What is a display?

   a. Wide use of displays.

   b. The need for displays.

2. Types of readings to be made.

   a. Check.

   b. Qualitative.

   c. Quantitative.

3. Kinds of displays in use.

   a. Examples of quantitative and qualitative displays.

   b. Examples of displays specific for sense modalities.

D. <u>Visual Displays</u>

1. Symbolic displays--dials and counters.

   a. Configuration.

      1) Shape.

      2) Size.

   b. Movement.

      1) Number of revolutions.

      2) Speed of movement.

   c. Scales.

      1) Number and spacing of markings.

      2) Origin and end of scale.

      3) Consistency of scale markings.

      4) Size.

d. Pointers.

1) Design.

2) Length and width.

e. Arrangement of dials.

1) Standardization.

2) Patterning.

3) Grouping.

f. Legibility.

1) Design.

2) Illumination.

3) Angle of viewing.

2. Pictorial displays.

a. Inside or outside referent.

b. Interpretability and training.

1) Simplicity.

2) Realism.

3. Warning signals and lights.

a. Color.

b. Design.

c. Placement.

E. Auditory Displays

1. Types.

2. Limitations.

F. Displays of Touch, Kinesthesis and Balance

1. Types.

2. Limitations.

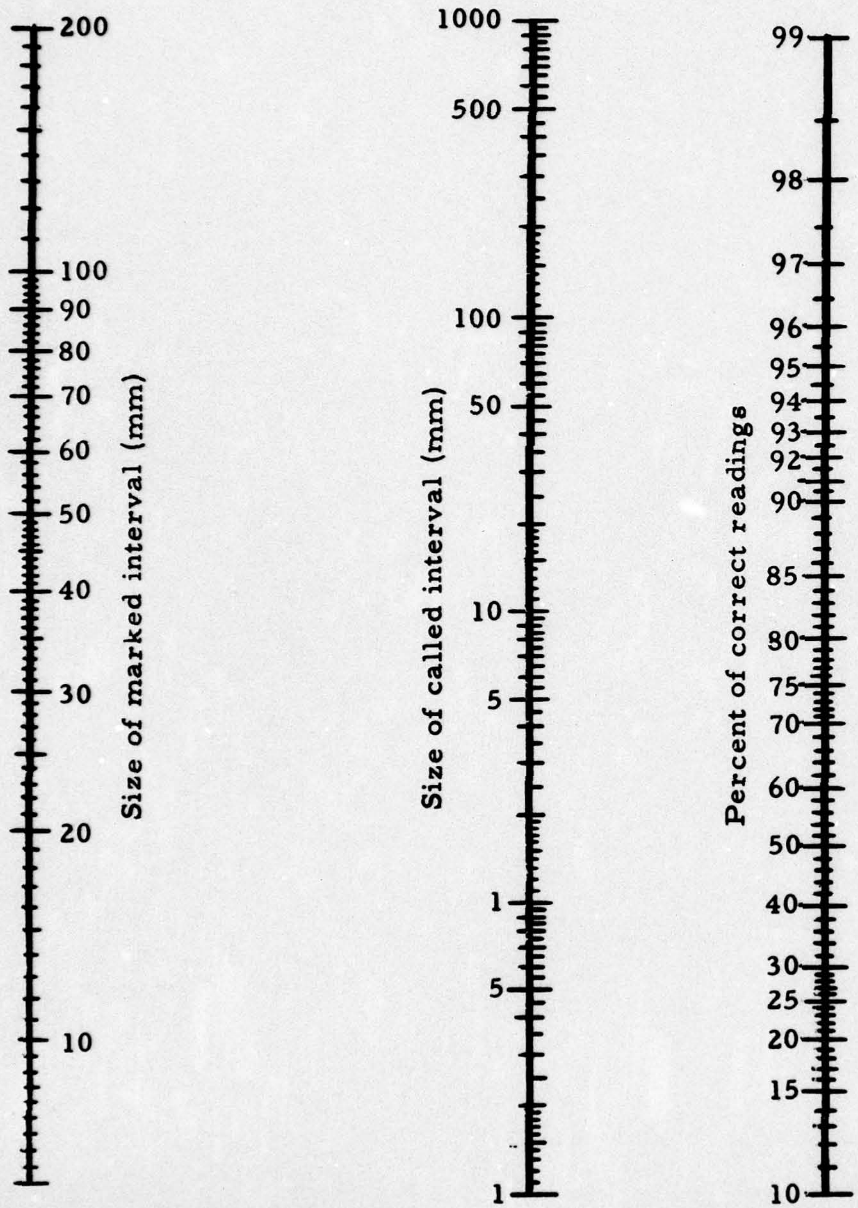
GENERAL AND INSTRUMENT ILLUMINATION*

	Desired	Permissible From	Permissible To
Brightness ratios, bright and dark conditions			
Various dial markings within a given instrument.	1:1	1:1	3:1
Instrument to background.	2:1	1:1	10:1
Various instruments within a given panel.	1:1	1:1	3:1
Cathode ray tube to background.	2:1	1:1	10:1
Brightness ratio of instrument markings to background.	100:1	15:1	400:1
Lighting requirements for bright conditions			
Illumination on working areas	10 fc	1 fc	10 fc
Brightness of markings on instruments	10 ml	2 ml	20 ml
Brightness of indicator lights	50 ml	40 ml	100 ml
Brightness of cathode ray tubes	.10 ml	.10 ml	1.0 ml
Red lighting requirements for dark adapted conditions			
Brightness level for orientation	.001 ml**	-	-
Illumination on working areas	.02 fc	.01 fc	.03 fc
Brightness of markings on instruments	.10 ml**	-	-
Brightness of indicator lights	.08 ml	.04 ml	.10 ml
Brightness of cathode ray tubes	.10 ml	.10 ml	1.0 ml

*Based on work of Medical Research Laboratory of the New London Submarine Base and of Dunlap and Associates, Inc.

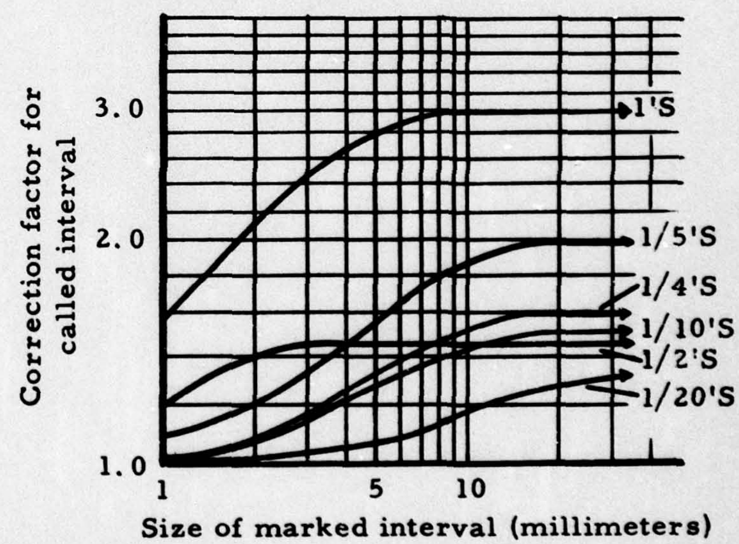
**The Medical Research Laboratory of the New London Submarine Base is reported to recommend a brightness of .10 millilambert for submarine dial markings under dark adapted conditions and an ambient illumination value of .001 millilambert for orientation purposes in non-working areas.

NOMOGRAPH FOR DETERMINATION OF SCALE INTERVALS



Percentage of correct readings to a given interval when the sizes of marked and called intervals are known.

Correction factors to be applied to size of called interval for various fractional interpolations as a function of the size of the marked interval.



TRAINING CONSIDERATIONS AFFECTING DESIGN

A. Introduction

B. Importance of Equipment Design to Training

1. Human engineering facilitates training.

2. Training costs time and money.

3. System design requires consideration of training.

   a. Incorporate a means of measuring performance.

   b. Provide facilities for on-site training.

4. Equipment designers must also provide training equipment.

5. Automation increases the need for proper training.

C. Why Training is a Problem

1. Administrative and economic considerations.

2. Equipment designers assume training can wait.

3. Operators are not engineers, geniuses, or identical.

4. Equipment is becoming more complex.

5. Training equipment becomes more complex.

6. Higher proficiency is required.

D. The Constraints Placed Upon Equipment Design by Human Learning Characteristics

1. For maximizing the value of training, the design of equipment must consider the features of human learning.

2. Principles for optimizing the rate of human learning.

   a. Task meaningfulness.

   b. Transfer of general principles.

   c. Perceptual relations in learning.

   d. The effect of scheduling practice on economy of learning.

   e. Procedural variables in performance.

   f. Guidance in training.

   g. Learning to learn.

   h. Removing conflicting behavior (unlearning)

   i. Overlearning.

   j. Active participation in learning.

E. *Effect of Equipment Design on Training*

1. Determine requirements for training.

   a. With established equipment, the problem is to integrate personnel into system.

   b. Where equipment can be manipulated, design to facilitate training.

2. Design considerations to meet the requirements of training.

   a. Ease of learning criterion.

   b. Population stereotypes and compatibility with standards.

   c. Information requirements for the learner.

   d. Provide job aids.

e. Coding and labelling.

f. Make logical sequences out of complex tasks.

3. Workspace layout for training.

4. Display and control optimization.

5. Special design where training cannot be accomplished.

6. Design for preventive maintenance.

7. Safety.

F. <u>Simulation</u>

1. Engineering--duplication of operational equipment within close tolerance specifications.

2. Psychological--transfer from the training (simulator) task to the operational situation.

HUMAN DECISION MAKING

A. Introduction

1. Automation of routine tasks has increased the relative importance of man's role as decision maker.

2. Future use of computers may change the nature of human decision making.

3. Important to understand human decision making in order to use humans and computers most effectively in combination.

B. Definitions

1. Decision: a voluntary time-bound choice of one out of a set of action alternatives.

2. Action alternatives:

   a. Adaptive: appropriate to system goal (e.g., fire missile, take cover, get more information, do nothing).

   b. Non-adaptive: not appropriate to system goal (e.g., smash radar scope, freeze at controls, etc.).

3. Correctness:

   a. If strategy is known, "correctness" is the degree to which action choice conforms to decision rules.

   b. If strategy is not known, "correctness" is degree of conformance to system goal.

4. Decision rules: usually the result of decisions made at higher level, but sometimes decision maker in the system has authority to change the rules (as one of his action alternatives).

C. Simplified Decision Analysis in a System Design

1. Decision is inferred from a behavioral choice among alternatives.

2. Graphic representation of information-decision-action sequence.

3. Design objective: to present information (inputs) and make available controls (outputs) so as to facilitate "correct" decisions.

4. Method: analyze rules as related to action alternatives, identify input and output requirements, apply human engineering principles.

5. Assumption: human will attempt to follow rules.

6. New methods needed to facilitate human decision making under uncertainty.

D. Methods of Classifying Decisions

1. Input and output characteristics:

   a. Single vs. multiple.

   b. Discriminability of input.

   c. Anticipated (pre-determined) vs. unanticipated inputs and outputs.

2. Static or "one-shot" vs. dynamic or sequential.

3. Tactical vs. strategic.

4. Certainty vs. uncertainty of outcome.

5. Risk vs. non-risk.

E. Factors Affecting Decision Behavior

1. Input characteristics:

   a. Number and type of alternatives.

b. Predictability or structuring.

c. Discriminability.

d. Rate of presentation (both very high and very low can degrade performance).

e. Choice of sensory modality.

f. Similarity between alternative signals.

g. Display design.

h. Knowledge of results.

2. Output characteristics:

a. Number and type of alternatives.

b. Relation to inputs.

c. Control design.

d. Degree of commitment implied in action alternatives.

e. Probability of successful action completion.

f. Feedback of action result.

3. Task environment characteristics:

a. Extremes of temperature, pressure, vibration, noise, etc.

b. Isolation, boredom, monotony.

c. Physical layout and psychological organization of the group.

d. Incentives--must be appropriate to individual's set of values.

4. Characteristics of the decision maker:

a. Cultural values.

b. Susceptibility to social pressures.

c. Personality characteristics and personal goals.

d. Previous experience and training.

F. Probabilistic Decision Making (Decisions Under Uncertainty)

Illustrative problem: aircraft identification and action selection.

1. Contingencies: The set of relevant situations that may be encountered due to nature or an opponent.

   F = Friendly   H = Hostile

2. Action alternatives: The set of discrete choices designed into the system and open to the decision maker.

   D = Drop Target   T = Track Target   E = Engage Target

3. Outcomes: All possible combinations of actions and contingencies.

4. Value or utility table: The values or losses to the system complex of each possible outcome.

   Loss table:

		Action alternatives		
		D	T	E
Contingency	F	0	1	3
	H	5	3	2*

*Note that if the action is to "engage" and the contingency is "hostile," there is still some loss to the system (but no "regrets"--see below).

5. Risk or "regret" table: Same as above, except that within each row, the outcome with the lowest loss is assigned zero risk, and other numbers in that row are reduced accordingly.

		Action alternatives		
		D	T	E
Contingency	F	0	1	3
	H	3	1	0

6. **Predictions:** Best guess as to contingency, based on available information.

F = Friendly   U = Unknown   H = Hostile

7. **Prediction reliability:** The measured or estimated chance of each prediction-contingency combination.

		Prediction F	Prediction U	Prediction H
Contingency	F	.60	.25	.15
	H	.20	.30	.50

8. **Contingency probability:** The observed probability of occurrence of each contingency.

9. **Strategy:** The set of pre-selected actions for each prediction. Thus, DDE means:

Prediction	Action
Friendly	Drop Target
Unknown	Drop Target
Hostile	Engage Target

10. **Loss:** The expected loss, L, for a given strategy is the sum of the products of the loss of utility for each action-outcome combination and the probability based on the prediction reliability. Thus, for strategy DDE:

Loss if Friendly = $0 \times .60 + 0 \times .25 + 3 \times .15 = .45$
Loss if Hostile = $5 \times .20 + 5 \times .30 + 2 \times .50 = 3.50$

11. **Expected loss table:** The expected loss for each strategy under each contingency.

	DDD	DDT	DDE	DTD	DTT	DTE	DED	DET	DEE	Etc.
F	0	.15	.45	.40	.40	.70	.75	.90	1.20	Etc.
H	5	4.00	3.50	3.40	3.40	2.90	4.10	3.10	2.60	Etc.

12. Bases for strategy selection (risk philosophy).

   a. Minimax loss strategy (minimize maximum loss).

   b. Minimax risk strategy (minimize maximum risk).

   c. Bayes strategy (includes contingency probabilities as additional input).

   d. Others.

G. Role of the Decision Maker

1. Within the system:

   a. Assess information (its validity and relationships).

   b. May estimate probability of contingencies.

   c. Select action according to pre-determined rules or strategy.

   d. May evaluate outcome and review the rules.

   e. Act.

   f. Assess feedback information.

   g. Re-evaluate contingency probabilities and prediction reliability.

   h. Communicate revised contingency probabilities and prediction reliability to strategist.

2. Outside (above) the system:

   a. Assess information (contingency probabilities, prediction reliabilities, probabilities of successful completion of actions and contingencies, super-system goals or values, other intelligence).

   b. Develop utility tables for systems below his level.

c. Select basis for strategy (risk philosophy).

d. Select strategy.

e. Revise as necessary.

3. System designer.

a. Try to predict contingencies and system strategy.

b. Provide sources and displays of relevant information.

c. Provide means for implementing actions.

d. Provide means for feedback.

e. Automate decision making where possible, but provide flexibility where necessary.

H. <u>Characteristics of Human Decision Makers</u>

1. Restricted information-handling capability.

2. Subject to effect of stress.

3. Good ability to perceive relationships--especially spatial (e.g., patterns).

4. Variability in willingness to act.

5. Individual values or utility tables (motivations) may vary widely.

6. Humans do not always act according to their expressed values.

7. Humans fairly good at estimating contingency probabilities.

8. Tendency to "perseverate"--persist in wrong choice despite new information.

9. Can learn to change strategy to meet new contingencies.

I. Use of Computers in Decision Making

1. Short-term memory: compute and store contingency probabilities, prediction reliability.

2. Select action according to pre-determined rules or strategy.

3. In some instances, predict consequence of action choice by time-compression, thereby permitting trial response.

4. Can reduce effects of human variability and interpersonal effects by obtaining fast consensus.

5. Useful as simulator--in training for decision making.

6. By imposing a structure on the decision situation, can force value system to become explicit.

EXPERIMENTAL METHODS FOR DESIGN AND EVALUATION

A. Introduction

1. Objectives of experimentation.

   a. To identify factors affecting system performance.

   b. Inter- and intra-individual variability.

   c. Variability due to equipment design.

   d. Effect of learning.

   e. Effect of task environment.

   f. Experimentation in human engineering in systematic attempt to determine what factors contribute significantly to performance.

   g. Analogy with equipment testing.

2. Example of performance variability.

3. Need for continuous evaluation of design decisions.

   a. Prior to hardware design.

   b. Prior to delivery of engineering model.

   c. After delivery of engineering model.

4. Value of experimental program.

   a. To ensure good early design decisions.

   b. To evaluate these decisions early enough to permit modification.

   c. To identify special problems in selection and training of personnel.

B. Types of Experiments

1. Laboratory studies (most artificial, but easiest to control).

    a. Basic research.

        1) Useful in formulating general statements about performance as a function of design.

        2) Study the independent variable over a wide range.

        3) Results form basis for handbooks.

    b. Applied research.

        1) Useful in answering specific design questions.

        2) Study only feasible range of values of independent variable, but get appropriate measures.

        3) Results useful primarily for specific application.

        4) Actual scores may not hold in the real situation, but trends usually will.

    c. Laboratory experiments usually focus on measuring one activity.

2. Simulator studies.

    a. Essentially a laboratory study, but with relatively greater degree of task simulation.

    b. Valuable in studying sequence of activities.

    c. Valuable in studying activities of more than one operator.

    d. Valuable in identifying problems of display and control design, panel layout, allocation of functions.

    e. Also useful in identifying training problems and in accomplishing certain types of training.

f. Simulator should be designed with flexibility for modification to permit testing various configurations.

3. Field tests.

a. Potentially the most useful, but most difficult to control.

b. Problems of scheduling.

c. Measures of human performance usually contaminated by other factors.

1) Often a design concept is erroneously rejected on basis of irrelevant faults in the test.

d. Objectives of field test must be kept clearly in mind.

1) To evaluate system concept, use highly skilled operators, wait for favorable environment, prepare equipment carefully.

2) To measure normal performance, use average operators, typical environments, realistic time requirements.

C. Problem Identification

1. Factors to consider in selecting problem for testing.

a. Amount of relevant data already available.

b. Degree of confidence in data.

c. Importance of the particular operation to system effectiveness.

d. Cost of testing.

2. Selection of "independent" variables (factors deliberately varied by experimenter).

a. Continuously variable quantity.

b. Discretely different design features.

c. Multi-variable experiments.

d. To compare different concepts, use best possible design of each.

e. Factors to consider in selecting independent variables:

1) Extent to which they are likely to affect performance (based on intuition, past experience, other studies).

2) Extent to which variables are realistic in terms of system constraints (e.g., maximum practical size of radar scope).

3) Pilot (i.e., preliminary) study on limited sample may help define relevant factors.

f. Make sure independent variables are well controlled or accurately measured.

3. What to measure ("dependent" variables).

a. Criterion should relate to system requirements (i.e., better for what?).

1) In evaluating a display, keep in mind how the operator will use it in the real situation.

b. Most commonly used measures.

1) Time.

a) Applicable in many military situations (e.g., detecting a target, reading a dial, reacting to alarm).

b) Sometimes minimum useful time (i.e., decrease beyond certain point has no practical value).

2) Accuracy.

a) Average, or "mean," score.

b) Variability.

c) Number of errors (beyond some tolerable limit).

(1) Number of times Condition A was "better" than Condition B.

d) How to increase task errors for experimental purposes.

(1) Increase rate of presentation.

(2) Degrade the environmental conditions (e.g., poor lighting).

(3) Present distracting task.

(4) Implications of the above on meaningfulness of scores.

3) Relationship between time and error scores.

4) Learning time.

5) User preferences.

a) Limitations.

(1) May not be related to performance or even to choice behavior--therefore, misleading when used by itself.

b) Advantages.

(1) Easy to obtain.

(2) Useful for certain applications (product acceptance).

(3) Preferences may affect performance--especially where other factors are about equal.

(4) Information about preferences may help "sell" unpopular item which is demonstrably superior in performance.

6) Record of voice communications useful in interpreting results.

D. Precautions in Experimental Design

1. Get measure of variable error.

2. Counterbalance trials to avoid bias.

   a. If duplicate equipments are available, use each subject on both units, to isolate equipment variability from operator variability.

3. If counterbalancing is difficult, randomize.

   a. Do not present problems in increasing order of difficulty.

4. If different subjects are tested on different methods, match the groups for experience, intelligence, general skill level.

5. Use "enough" subjects or trials.

   a. Sensitivity of the experiment varies as the square root of N (i.e., to double your confidence in the results, must quadruple N).

   b. "Enough" depends on variability of the performance measure and on practical significance of difference.

6. Instructions to subjects are important (speed vs. accuracy).

   a. Should be simple, understandable, and consistent for all subjects.

7. Train subjects on task before taking measurements, to avoid effect of learning (unless learning time is one of your measures).

8. Randomize test patterns to prevent subject from learning the sequence.

9. Motivate the subjects.

E. Selection of Subjects

1. To minimize variability due to subjects, use homogeneous group.

2. To obtain representative scores, use representative sample.

   a. Experienced vs. naive.

   b. Engineers vs. Army population.

F. Precautions in Interpreting Results

1. Refer back to test objectives.

2. Qualify results in view of artificialities.

3. Scores may be relatively, but not absolutely valid.

4. Differences may be statistically, but not practically significant.

5. Trends may be practically, but not statistically important.

PART II. BIBLIOGRAPHIES

The general bibliography consists of items found to be helpful over a period of years. Some items are not necessarily in the field of human engineering but they may provide a convenient starting point for a bibliographical search in such related areas as statistics, operations research and personnel selection. It is followed by subject matter bibliographies related to each of the manuals in this series.

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PART III. CHECKLISTS

CHECKLIST
FOR
CONDUCTING A HUMAN FACTORS PROGRAM

The following checklist indicates the level of detail and the scope of applicability which should be covered in conducting a human factors program. In attempting to apply each item on the list, a number of questions will naturally arise. They will involve, for example, the applicability of each checklist item to the problem at hand, the meaning of the terminology, and the required level of detail. Intelligent application of the checklist requires some background in and familiarity with human factors engineering problems. From the administrator's standpoint, this can be developed quickly by reading a few selected references in the bibliography on the application of human factors engineering.

Requirements Determination and Functional Analysis	Yes	No	N/A
1. Operational and performance requirements for the "larger system" have been reviewed.	____	____	____
2. Requirements which the preceding impose upon the subsystem or equipment in question have been analyzed.	____	____	____
3. Required functions for subsystems or equipments have been established.	____	____	____
Planning, Organization and Analysis			
4. Functions, operations, duties and responsibilities have been allocated.	____	____	____
5. Descriptive models of over-all operation have been generated as appropriate:			
a. Flow charts	____	____	____
b. Decision sequence diagrams	____	____	____
c. Mathematical relationships	____	____	____

	Yes	No	N/A
d. Time-line charts	___	___	___
e. Link value charts	___	___	___
6. Input-output requirements for each operator and maintenance technician have been established.	___	___	___
7. The general requirements for each work area and the personnel who will occupy it have been delineated.	___	___	___
Design Requirements			
8. Human information and response requirements have been analyzed for each detailed operator task.	___	___	___
9. Requirements for control, display, and communication have been established.	___	___	___
10. The possibilities for applying special techniques for display, control and data processing have been evaluated.	___	___	___
11. Literature search, part-task simulation and experimental studies have been conducted where required to obtain needed data.	___	___	___
Design Development			
12. Design of displays, controls, panels, consoles, auxiliary equipment and workspaces has been subjected to detailed human factors engineering design considerations. (See accompanying checklists covering these subjects.)	___	___	___
13. Sketches, mock-ups, and blueprints of displays, controls, panels, consoles, etc., have been developed as appropriate.	___	___	___

	Yes	No	N/A
14. Sketches, etc., have been evaluated and subjected to engineering feasibility, schedule and cost considerations.	___	___	___
15. A final design review has been held.	___	___	___
Manning			
16. Manuals and handbooks describing the procedures for operating, maintaining and utilizing the equipment have been developed.	___	___	___
17. Detailed descriptions of the functions and tasks performed by each individual and the job element involved have been developed.	___	___	___
18. The levels of skill required and the number and type of people involved (using military personnel skill categories) have been established.	___	___	___
Evaluation			
19. Mock-up and drawing evaluation has been conducted in earlier stages to obtain useful feedbacks of design information.	___	___	___
20. Prototype equipment evaluation has been conducted where applicable or possible.	___	___	___
21. Laboratory operational evaluation has been carried out prior to field tests.	___	___	___
22. Field environment evaluation program has been conducted.	___	___	___
23. Requirements for human operational evaluation for user acceptance testing have been generated.	___	___	___

CHECKLIST
FOR
MAINTAINABILITY DESIGN PRACTICE

The process of maintenance may be divided into several characteristic parts:

1. Trouble prevention (preventive maintenance).

2. Trouble detection.

3. Trouble localization (trouble shooting).

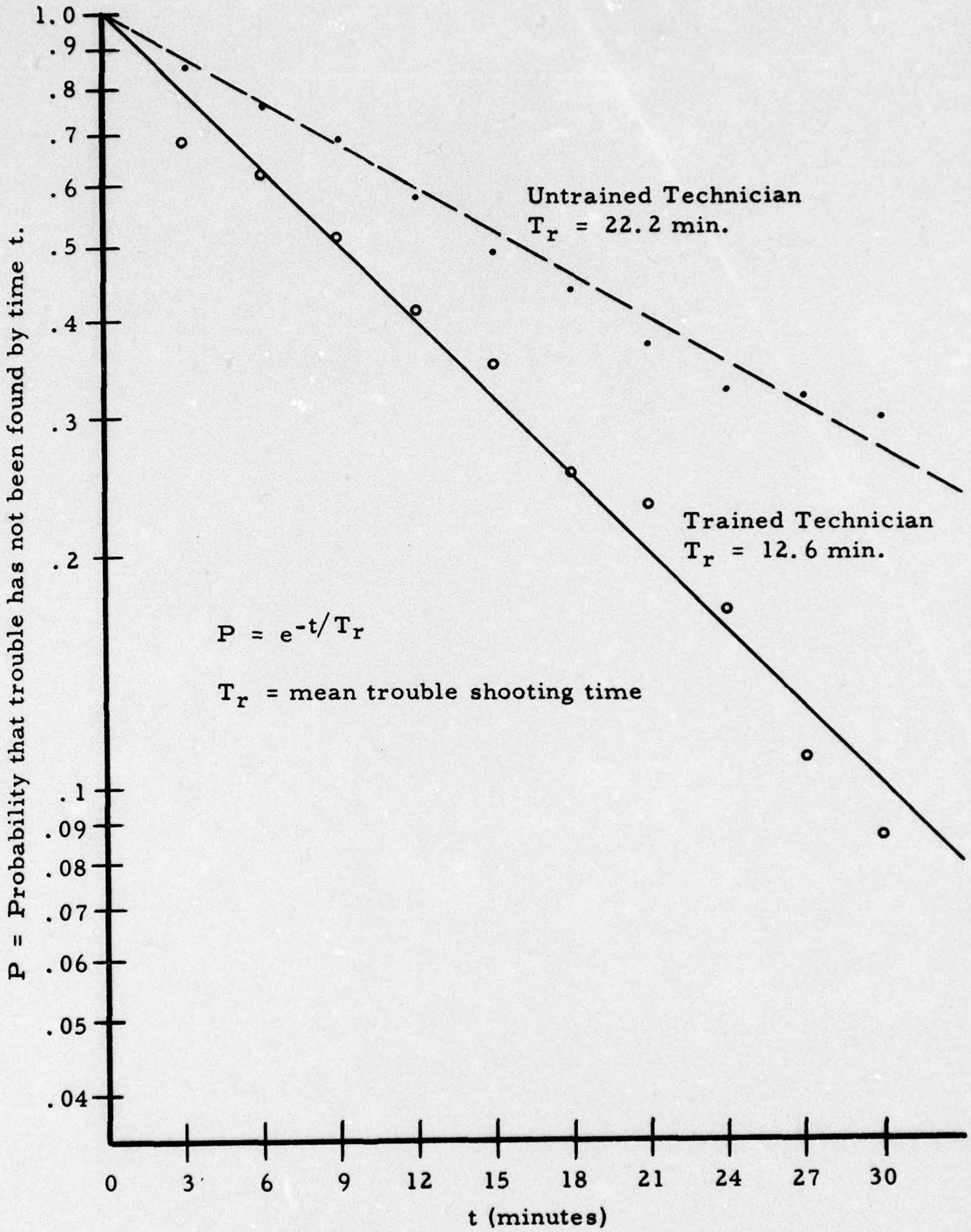
4. Repair or replacement of defective part.

5. Checkout and/or calibration.

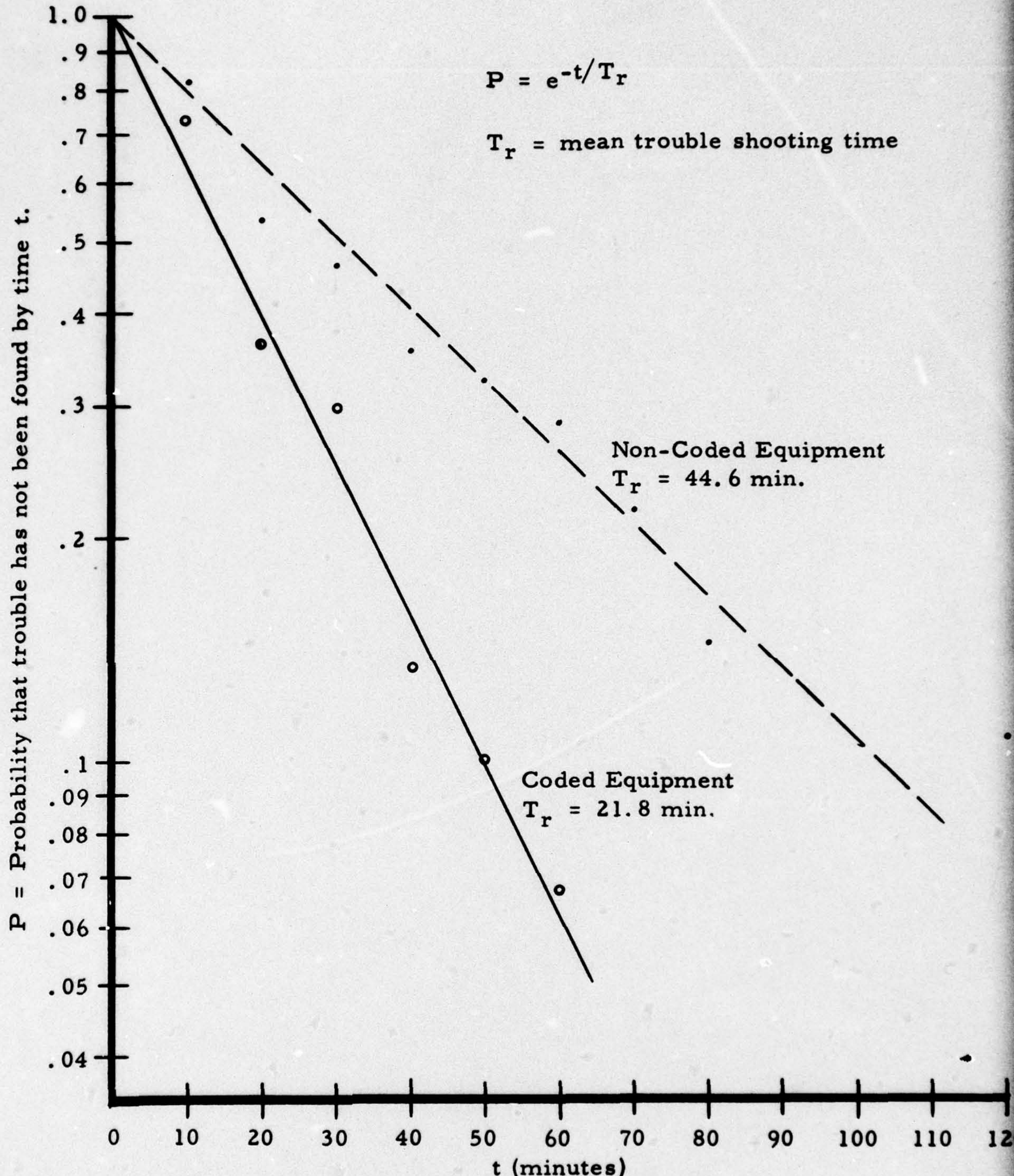
Equipment "down time" directly depends upon the amount of time spent in each of the above activities. This, in turn, depends upon the complex interaction between: a) how smart, motivated, and experienced the technician is, and b) how hard we make it for him by unthinkingly designing into the equipment "features" which make any or all of the five maintenance activities noted above difficult or even impossible to carry out.

The following three figures indicate the relative effects of training and design factors upon only one of the five maintenance activities, namely, trouble shooting. It is evident that the potential reduction in total equipment down time that could be achieved through proper design is tremendous.

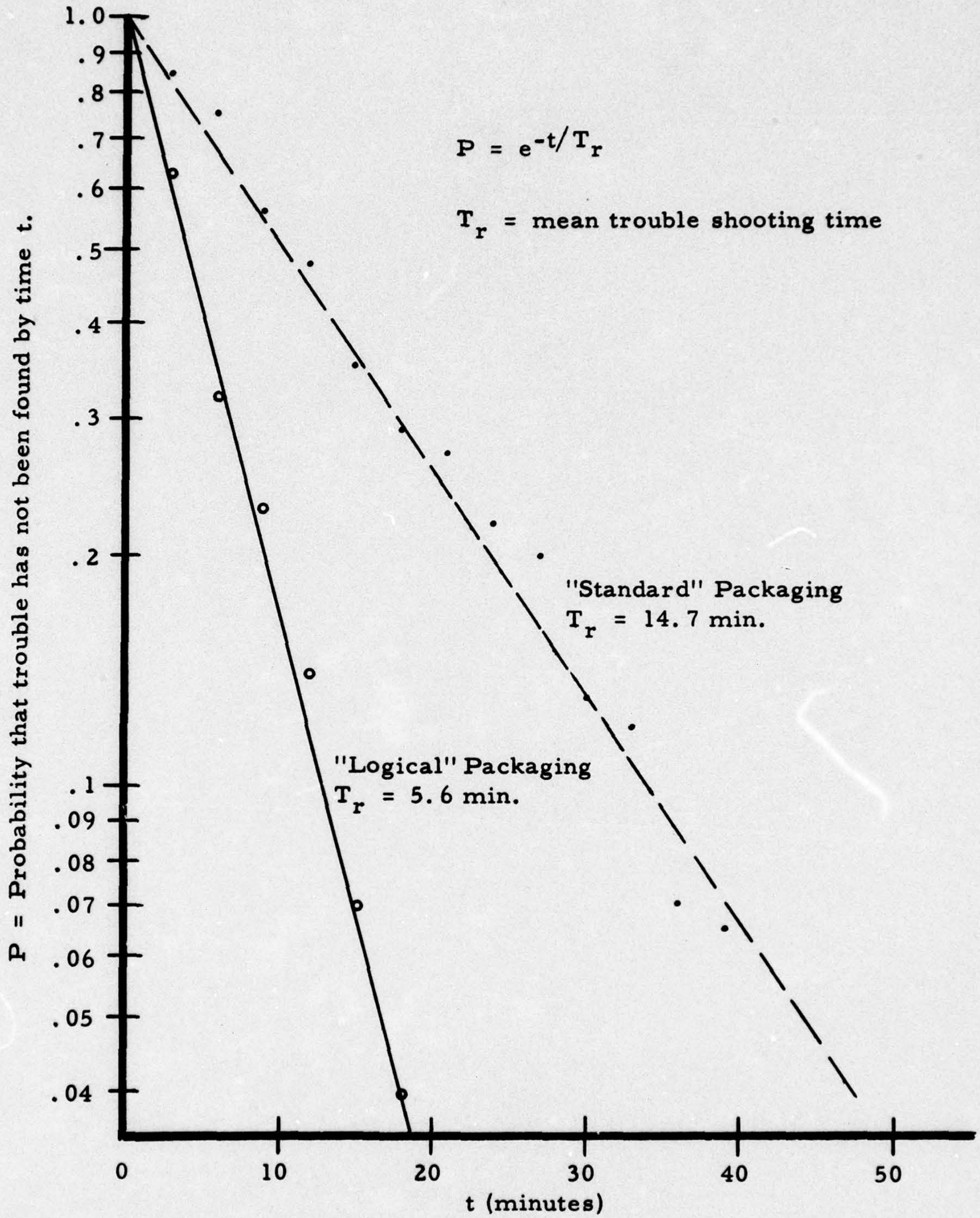
It is at the drawing board where most of the benefits of design for maintainability can accrue. To give some idea of the types of considerations that should be taken into account in the design stage, the following partial checklist of design practice considerations for maintainability is included. This checklist is not meant to be inclusive, and in fact deals primarily with the activity of repair and/or replacement. However, it should be sufficient to illustrate how maintainability design factors can be anticipated at the drawing board.



Effect of Training (Radio Receiver)



Effect of Coding (CRT Oscilloscope)



Effect of Packaging (Radar Simulator)

CHECKLIST
FOR
MAINTAINABILITY DESIGN PRACTICE

	Yes	No	N/A
Handles			
1. When possible, handles are provided on covers, drawers and components to facilitate handling.	____	____	____
2. Recessed rather than extended handle fixtures are provided to conserve storage space or to preclude injury by accidental striking of the handles.	____	____	____
3. When handles cannot be provided, hoist and lift points are clearly marked.	____	____	____
4. When possible, handles are located over the center of gravity to prevent the object from tipping while being lifted or carried.	____	____	____
5. Handles are positioned so that they cannot catch on other units, wiring, protrusions, or structural members.	____	____	____
6. Handles are placed on any component which might be difficult to grasp, remove, or carry or wherever there is a tendency to use fragile components as hand holds.	____	____	____
7. The following dimensions are minimum for handles to be used by the ungloved hand:			
a. Weight to be lifted or moved is under 25 lbs:			
Handle diameter: 1/4-1/2 inch	____	____	____
Finger clear: 2 inches	____	____	____
Handle width: 4-1/2 inches	____	____	____

	Yes	No	N/A
b. Weight to be lifted or moved is over 25 lbs:			
Handle diameter: 1/2-3/4 inch	____	____	____
Finger clear: 2 inches	____	____	____
Handle width: 4-1/2 inches	____	____	____
Covers, Cases and Access Doors			
8. Method of opening a cover is evident from the construction of the cover itself. If not, an instruction plate is permanently attached to the outside of the cover.	____	____	____
9. Hinges are used where possible to reduce the number of fasteners required.	____	____	____
10. When a hinged cover is used, a space equal to the swept volume of the cover is provided (e.g., opening of the cover is not obstructed by bulkheads, brackets, etc).	____	____	____
11. Structural members, other components, etc., do not interfere with removal of a cover.	____	____	____
12. Provision has been made for adequate bonding of plastic or rubber stripping and seals, so that if a cover comes into contact with or must slide over such material the seal will not be damaged or the cover jammed.	____	____	____
13. On test equipment, the lid or cover itself has adequate storage space for leads, adapters, etc.	____	____	____
14. It is evident when the cover is in place but not secured.	____	____	____
15. Ventilation holes are sufficiently small to prevent insertion of test probes, screwdrivers, or other tools.	____	____	____

	Yes	No	N/A
16. Cases are sufficiently larger than the components they cover that wires and other components will not be damaged when the cases are put on or taken off.	___	___	___
17. Where possible, cases are designed to lift off the components rather than the components lifted out of the cases.	___	___	___
18. Where feasible, guides, tracks, and stops are provided to facilitate handling and to prevent damage to components.	___	___	___
19. Access doors are hinged at the bottom if possible.	___	___	___
20. When access doors must be hinged at the top, a support rod is provided to hold the cover open.	___	___	___
21. Hinged doors or covers are provided with captive quick-opening fasteners.	___	___	___
22. If a hinged access or its quick-opening fasteners do not meet stress, pressurization, shielding, or safety requirements, a minimum number of the largest screws consistent with these requirements are used.	___	___	___
23. If instructions applying to a covered unit are lettered on a hinged door, the lettering is properly oriented for reading when the door is open.	___	___	___
24. A minimum number and type of fasteners are used, commensurate with requirements for stress, bonding, etc.	___	___	___
25. When possible, the same size and type of fasteners are used for all covers, cases and access doors.	___	___	___

	Yes	No	N/A
26. Maximum use is made of tongue-and-slot catches to minimize the number of fasteners required.	___	___	___

NOTE: HAND-OPERATED FASTENERS REQUIRING NO TOOLS ARE PREFERRED; THOSE REQUIRING STANDARD HAND TOOLS ARE ACCEPTABLE; THOSE REQUIRING NON-STANDARD TOOLS SHOULD NOT BE USED.

	Yes	No	N/A
27. Where compatible with stress and load considerations, fasteners for mounting components and equipment require at most one complete turn.	___	___	___
28. If bolts are required, a minimum number of turns are required to tighten or loosen them.	___	___	___
29. Captive nuts and bolts are used where feasible.	___	___	___
30. Bolts requiring high torque are provided with hexagonal heads.	___	___	___
31. To prevent stripping of threads, screws of different threads are of different diameters.	___	___	___

Accessibility

Information placed at each access includes the following:

	Yes	No	N/A
32. Nomenclature of items accessible through it.	___	___	___
33. Names of auxiliary equipment to be used at it.	___	___	___
34. Periods for accomplishing operations.	___	___	___
35. Warnings of hazardous or critical operations.	___	___	___

	Yes	No	N/A
36. Edges of accesses have internal fillets or other protection if they might otherwise cause injury to hands or arms.	___	___	___
37. Access provisions are located on easily accessible surfaces.	___	___	___
38. Components are not placed in recesses or located behind or under stress members, floor boards, seats, hoses, pipes, or other items which are difficult to remove.	___	___	___
39. Check and adjustment points, cable end connectors, and labels are accessible and, where possible, face the operator.	___	___	___
40. Access to functions which the technician must observe are large enough for adequate view.	___	___	___
When visual access only is required, the following practices in order of preference are followed:			
41. Opening with no cover is used unless this is likely to degrade system performance.	___	___	___
42. Plastic window is used if dirt, moisture, or other foreign materials are a problem.	___	___	___
43. Break-resistant glass window is used if physical wear or contact with solvent will cause optical deterioration.	___	___	___
44. Quick-opening metal cover is used if glass does not meet stress or other requirements.	___	___	___
When access for tools, test leads, and service equipment is required, the following practices in order of preference are followed:			
45. Opening with no cover is used unless this is likely to degrade system performance.	___	___	___

	Yes	No	N/A
46. Sliding or hinged cap is used if dirt, moisture, or other foreign materials are a problem.	___	___	___
47. Quick-opening cover plate is used if a cap will not meet stress requirements.	___	___	___
48. Unless a component is completely self-checking, provision has been made for checking operation of that unit in the operating condition without the use of special rigs and harnesses.	___	___	___

Lifting and Carrying

	Yes	No	N/A
49. Equipment is modularized such that weight of removable components is below 20 pounds whenever possible.	___	___	___
50. Materials or components to be carried short distances by one man do not exceed the values given in the following table.	___	___	___

Maximum allowable weight (lbs)	Height lifted from ground (ft)
142	1
139	2
77	3
55	4
36	5
20	6

Reaching

Smallest allowable openings for one-hand tasks are as follows:

	Yes	No	N/A
51. Inserting empty hand held flat: 2-1/2 by 4-1/2 inches.	___	___	___
52. Smallest square hole through which empty hand can be inserted: 3-1/4 by 3-1/4 inches.	___	___	___
53. Inserting miniature vacuum tube, held with the thumb and first two fingers, up to the center knuckle of the middle finger: 2 by 2 inches.	___	___	___

	Yes	No	N/A
54. Using 8-inch screwdriver with a 1-inch diameter handle: 4 by 4 inches.	___	___	___
55. Inserting and tightening AN plug (14-pin connector, outside diameter of 1-7/8 inches): 4-1/4 by 4-1/4 inches.	___	___	___
56. Inserting small box (or electric assembly): diameter of the box plus 1-3/4 inches.	___	___	___
Smallest allowable openings for two-hand tasks are as follows:			
57. Inserting drawer or electronic assembly grasped by handles on front, into opening: 1/2 inch clearance on each side of assembly.	___	___	___
58. Reaching through opening with both hands to depth of 6 to 25 inches: width, three-quarters the depth of reach; height, 4 inches.	___	___	___
59. Reaching in to full arm length (to shoulders), straight ahead, with both arms: width, 20 inches; height, 4-1/4 inches.	___	___	___
<u>Location of Replaceable Components</u>			
60. Large components which are difficult to remove are mounted so that they do not prevent access to other components.	___	___	___
61. Components are located so that each replaceable unit can be removed through a single access panel.	___	___	___
62. Components are located where dirt or oil will not drop on them or on the technician performing maintenance tasks.	___	___	___
63. Components are placed to allow sufficient space for use of test equipment and other required tools without difficulty or hazard.	___	___	___

	Yes	No	N/A
64. All throwaway components are accessible without removal of other components.	___	___	___
65. Structural members of the chassis do not prevent access to components.	___	___	___
66. Delicate components are so located or guarded that they will not be damaged while the unit is being handled or worked on.	___	___	___
67. Components are located so that blind adjustments are not necessary.	___	___	___
68. If screwdriver adjustments must be made blind, mechanical guides are provided or the screws are mounted so that the screwdriver will not fall out of line.	___	___	___
69. Sensitive adjustments are so located or guarded that they cannot be accidentally disturbed.	___	___	___
70. Components of the same or similar form, such as tubes, are mounted with a standard orientation throughout, but are readily identifiable and distinguishable.	___	___	___
71. Internal controls are located at a safe distance from dangerous voltages.	___	___	___
72. Equipment is modularized so that rapid and easy removal and replacement of malfunctioning modules or components can be accomplished by one technician.	___	___	___
73. Components can be checked and adjusted separately and then connected together into the system with minimum adjustment.	___	___	___

Component Mounting	Yes	No	N/A
74. Whenever possible, components are so located that no other equipment must be removed to gain access or to remove them.	___	___	___
75. If it becomes necessary to place one component behind another, the component requiring less frequent access is in the rear.	___	___	___
76. Components frequently removed for checking from their normal installed position are mounted on roll-out racks, slides, or hinges.	___	___	___
77. Limit stops are provided on roll-out racks and drawers; override of these limit stops is easily accomplished.	___	___	___
78. Field removable components are replaceable with common handtools.	___	___	___
79. No more than four screws or bolts are used for mounting a major component in an installation.	___	___	___
80. Components are mounted to the housing rather than attached to each other so only the component to be replaced has to be removed.	___	___	___
81. Replaceable components are plug-in rather than solder connected.	___	___	___
82. Removal of any replaceable component requires opening or removal of a minimum number of covers or panels (preferably one).	___	___	___
83. Guide pins or their equivalent are provided on components for alignment during installation.	___	___	___
84. Physically similar but electrically non-interchangeable components are so keyed that it is impossible to insert a wrong unit.	___	___	___

	Yes	No	N/A
85. Components are coded (e.g., by means of labels) to indicate the correct unit and its orientation for replacement.	___	___	___
86. If mounting screws must pass through covers or shields for attachment to the basic chassis of the component, the screw holes are large enough for passage of a screw without perfect alignment.	___	___	___
87. Components are laid out so that a minimum of place-to-place movement by the operator is required during checkout.	___	___	___
88. Components are located and mounted so that access to them may be achieved without danger to personnel (e.g., from electrical charge, heat, sharp edges and points, moving parts, chemical contamination).	___	___	___
89. Access to units maintained by one operator does not require removal of equipment by a second higher-skilled operator.	___	___	___
90. Components, such as tube sockets, are oriented in a uniform direction to facilitate component replacement.	___	___	___

Conductors and Cables

	Yes	No	N/A
91. Conductors are bound into cables and held by means of lacing twine or other acceptable means.	___	___	___
92. Long conductors or cables, internal to equipment, are secured to the chassis by cable clamps.	___	___	___
93. Cables are long enough so that drawers or slide-out racks can be opened without breaking electrical connections.	___	___	___

	Yes	No	N/A
94. Cables are long enough so that each functioning component can be checked in a convenient place or, if this is not feasible, extension cables are provided.	___	___	___
95. Cables are long enough to permit jockeying or movement of components when it is difficult to connect or disconnect other cables.	___	___	___
96. If it is necessary to route cables and wires through holes in metal partitions, protection from mechanical damage is provided by grommets or other acceptable means.	___	___	___
97. Guards or other safety devices are provided for easily damaged conductors such as wave guides or high-frequency cables.	___	___	___
98. Electrical cables are not routed below fluid lines.	___	___	___
99. Cables cannot be pinched by doors, lids, etc.	___	___	___
100. Cables are routed so they cannot be walked on or used for hand holds.	___	___	___
101. Cables are easily accessible for inspection and repair.	___	___	___
102. Cables are so routed that they need not be bent or twisted sharply or repeatedly.	___	___	___
103. Input and output cables, with the exception of test cables, do not terminate on a control-display panel.	___	___	___
104. If test cables terminate on control-display panels, test receptacles are located so that their associated cables do not interfere with control and displays.	___	___	___

	Yes	No	N/A
105. If feasible, individual conductors of all cables, either single- or multi-conductor, are color-coded their entire length.	___	___	___

Connectors

	Yes	No	N/A
106. One-turn or other quick-disconnect plugs are used.	___	___	___
107. When dirt and moisture are a problem, plugs have an attached cover.	___	___	___
108. Connectors are located far enough apart so that they can be grasped firmly for connection and disconnection.	___	___	___
109. Rear of plug connectors is accessible for test and service, except where this is precluded by potting, sealing, etc.	___	___	___
110. Plugs or receptacles are provided with aligning pins or other alignment devices.	___	___	___
111. Aligning pins on plugs project beyond the electrical pins.	___	___	___
112. Plugs are designed so that it is impossible to insert the wrong plug in a receptacle.	___	___	___
113. Socket rather than plug contacts are "hot."	___	___	___
114. Connectors and their associated labels are positioned for full view by maintenance personnel.	___	___	___
115. Connecting plugs and receptacles are identified by color or shape or other acceptable means.	___	___	___
116. Plugs and receptacles have painted stripes, arrows, or other indications to indicate proper insertion of aligning pins.	___	___	___

	Yes	No	N/A
Test Points			
117. Test points to determine that a unit is malfunctioning are provided.	___	___	___
118. Appropriate test points are provided when a component is not completely self-checking.	___	___	___
119. Primary echelon test points are so located and coded that they are readily distinguished from secondary echelon test points.	___	___	___
120. When feasible, primary echelon test points are grouped in a line or matrix to reflect the sequence of tests to be made.	___	___	___
121. Primary echelon test points used for component adjustment are located close to the controls and displays also used in adjustment.	___	___	___
122. Test points are not obstructed by cables, components, etc.	___	___	___
123. Test points are appropriately labeled by symbol or name.	___	___	___
124. Test points are clearly identified for easy location in the assembly by a contrasting color.	___	___	___
125. Job instructions coded to test points are provided when it is not feasible to provide full or detailed information at the test points.	___	___	___
126. Desired signal and tolerance limits of test points are specified, preferably at the test points themselves.	___	___	___
127. Contact points of test points have sufficient strength to prevent their bending.	___	___	___
128. When feasible and not in conflict with other requirements, a secondary echelon test point is supplied at the input and output of each throw-away component.	___	___	___

	Yes	No	N/A
Fuzes and Circuit Breakers			
129. Fuzes and circuit breakers are so located that they can be easily seen and quickly replaced or reactivated.	___	___	___
130. Fuze replacement is not hampered by other components.	___	___	___
131. No special tools are required for fuze replacement.	___	___	___
Tools			
132. Variety of tools is held to a minimum.	___	___	___
133. As few special tools as possible are required.	___	___	___
134. Tools to be used near high voltage are adequately insulated.	___	___	___
135. Metal handles are avoided on tools likely to be used in extreme cold or heat.	___	___	___
136. Tools are of dull finish to avoid glare in strong light.	___	___	___
137. Speed and ratchet-type tools are provided when necessary.	___	___	___
138. Nonsparking tools are provided for use in an explosive atmosphere.	___	___	___
Lubrication			
139. Equipment containing mechanical components either has provision for lubrication without disassembly or does not require lubrication.	___	___	___
140. When lubrication is required, the type of lubricant to be used and the frequency of lubrication is specified by a label at or near the lubrication point.	___	___	___

CHECKLIST
FOR
WORKPLACE LAYOUT

	Yes	No	N/A
Over-All Workplace Layout			
1. All workplace dimensions are selected to accommodate 95% of the body sizes and movements of the population of expected operators, including the full range of clothing which they must wear.	___	___	___
2. Adequate space is provided for each operator in front of the equipment on which he must work.	___	___	___
3. Each operator can leave his working position and the compartment without disturbing any other operator.	___	___	___
4. Operators who must communicate directly with each other verbally are located close to each other and can see each other's faces at their operating positions.	___	___	___
5. Adequate space is provided so that a maintenance technician can enter the compartment and work effectively on any single console in an emergency without disturbing the personnel at other work stations.	___	___	___
6. Aisle space and access aisles to operating positions are clear to allow for continuous traffic where required.	___	___	___
7. From their operating positions, supervisors can observe all the personnel in the compartment under their charge.	___	___	___
8. Where common displays must be viewed, all of the operators requiring information from them have a clear line of sight from their operating positions.	___	___	___

	Yes	No	N/A
9. Hooks for clothing and stowage space for other personal gear are provided if needed.	____	____	____
10. Emergency equipment is provided in easily accessible locations and clearly marked.	____	____	____
11. Ladders, climbing rungs, hand-holds and rails, walkways, etc., are present if needed and are large enough and provide sure footing and gripping, even under icy or highly waxed conditions.	____	____	____
12. Both mechanical and electrical interlocks are provided to prevent energizing or movement of equipment when men are in positions which would be dangerous under these conditions. These interlocks cannot be shorted out when a man is in a position which would be dangerous.	____	____	____
13. If noise levels, distance, or other factors prevent verbal communication, and communication is required, a clear line of sight is provided so that visual (like hand) signals can be used.	____	____	____

<u>Equipment Form Factors--General</u>

14. The major display for each operator is mounted perpendicular to his normal line of sight.	____	____	____
15. Other important displays are mounted as close to perpendicular to the operator's normal line of sight as feasible.	____	____	____
16. Writing space is provided where tasks involve the use of books, manuals, or forms.	____	____	____
17. Equipment units on top of which men must work have their tops at the same level, and spaces between units are less than two inches wide. Non-skid surfaces are applied to the tops of such units, and rails and hand-holds are present.	____	____	____

	Yes	No	N/A
Equipment Form Factors--Seated Operators			
18. Knee and foot room is provided beneath panel surfaces. Minimum dimensions are 25 inches high, 20 inches wide, and 18 inches deep.	___	___	___
19. The height of the writing surface above the floor is 29 inches.	___	___	___
20. Over-all console height does not exceed 62 inches. If it is desirable for operator's line of sight to extend beyond the console, over-all console height does not exceed 48 inches.	___	___	___
Equipment Form Factors--Standing Operators			
21. Visual displays on vertical panels are mounted in an area no higher than 70 inches and no lower than 40 inches above the standing surface.	___	___	___
22. Precise-reading indicators and important controls are placed in an area no higher than 64 inches and no lower than 48 inches above the standing surface.	___	___	___
23. Controls mounted on vertical panels are located in an area no higher than 70 inches and no lower than 30 inches above the standing surface.	___	___	___
24. Precise controls or controls which are operated frequently are mounted between 40 and 55 inches above the standing surface.	___	___	___
25. A 4-inch by 4-inch toe space is provided along the bottom front of each rack.	___	___	___
Seating			
26. The seat itself is at least 16 inches square.	___	___	___
27. A seat-height adjustment of 19 ± 2 inches (minimum) is provided.	___	___	___

	Yes	No	N/A
28. If a high chair is required, a vertically-adjustable foot rest is provided.	___	___	___
29. The seat is essentially flat under no load.	___	___	___
30. The seat, back, and arms are padded.	___	___	___
31. Arms are provided on the seat, which are a minimum of 2 inches wide and 10 inches long.	___	___	___
32. The chair is on casters in a fixed or leveled installation and is <u>not</u> provided with casters for a vehicular installation.	___	___	___
33. In a vehicular installation, some method of tie-down to prevent the chair from shifting is provided.	___	___	___
34. The seat back makes an angle of 90 to 110 degrees with the seat surface.	___	___	___
35. The seat back is at least 15 inches square.	___	___	___

Layout of Panels and Units

	Yes	No	N/A
36. Primary controls and displays are placed within the optimal visual and manual spaces on the console or unit.	___	___	___
37. Emergency controls and displays are placed in readily accessible positions with critical emergency controls and displays located in optimal visual and manual areas.	___	___	___
38. The emergency controls which affect the equipment extensively if operated require at least two distinct motions to operate them. That is, they are guarded or otherwise shielded from inadvertent operation.	___	___	___
39. Secondary controls and displays are placed within the limiting visual and manual areas, but are not necessarily in the optimal areas.	___	___	___

	Yes	No	N/A
40. Set-up, calibration, or test controls and displays are given lowest priority location, placed outside the operator's normal work area, or placed behind access doors.	___	___	___
41. Displays which must be check-read are grouped together.	___	___	___
42. When displays are used sequentially, they are aligned horizontally from left to right as close to each other as possible.	___	___	___
43. Every control and display on the panel has a descriptive legend associated with it.	___	___	___
44. The operator's hand does not block the view of the display when he operates an associated control.	___	___	___
45. Controls associated with use by the right hand are located below or to the right of their displays, and vice versa for controls operated by the left hand.	___	___	___
46. There is an adequate separation between controls so that they can be operated easily without inadvertent operation of adjacent controls.	___	___	___
47. Controls which must be adjusted as an operator observes a display or looks through optics can be reached and adjusted easily by the same operator as he views the visual display involved.	___	___	___

CHECKLIST
FOR
THE ENVIRONMENT OF MAN

The Physical Environment

	Yes	No	N/A
Lighting			
1. Adequate general illumination is supplied for movement of personnel without visual hindrance. This normally means a minimum of about 5 footcandles of illumination.	___	___	___
2. Illumination levels between 25 and 50 foot-candles are provided on all work surfaces and panels where specific requirements for low level illumination are not present.	___	___	___
3. Local light units are provided for exacting visual tasks where required, or where general illumination is inadequate.	___	___	___
4. Luminaires and reflecting surfaces (like scope faces and meter cover glasses) are so arranged in relation to each other that no glare is present at the eye of the operator in his normal operating position.	___	___	___
5. Work surfaces and panel faces have a matte finish.	___	___	___
6. Panels have a brightness ratio of no greater than 1:5 from darkest to lightest areas.	___	___	___
Air Condition			
7. Temperature is controllable within the range of 65 to 80°F to ± 2° under all ambient temperature conditions. (This range should be lower for operations requiring a great amount of activity by operators.)	___	___	___

	Yes	No	N/A
8. No large surface has a surface temperature greater than 10°F different from the controlled air temperature.	___	___	___
9. Air conditioning is provided if the effective temperature exceeds 90°F.	___	___	___
10. Air speed is less than 50 fpm in the vicinity of working positions.	___	___	___
11. Humidity is controlled between 30 and 70%.	___	___	___
12. Provision is made to control noxious fumes and gases, dusts and odors below perceptible levels, or below levels which are likely to produce some undesirable physiological effects for the exposure periods involved.	___	___	___
13. An adequate volume per unit time of clean air is provided as a function of compartment volume and number of operators.	___	___	___
Noise, Vibration and Shock			
14. Vibration is controlled so that levels applied to the operator are less than 0.01G.	___	___	___
15. Maximum integrated noise level is no more than 85 db.	___	___	___
16. Where frequent conversation is required between operators, maximum integrated noise level is no more than 70 db.	___	___	___
17. Where exposure to high noise levels is required, operators are supplied with and required to wear ear protection.	___	___	___
18. Care is taken to insure that operators are not exposed to shock waves whose peak overpressure exceeds 2.5 pounds per square inch.	___	___	___

The Social Environment

Individual Job Design	Yes	No	N/A
Independence			
1. An adequate amount of independence is achieved through mechanization.	___	___	___
2. Tasks are combined (job enlargement) so that optimum independence and maximum interest are achieved.	___	___	___
3. Dependence on others is fostered wherever it is necessary to facilitate learning, to provide a double check on accuracy, or to allow utilization of the highest degree of skill available.	___	___	___
Interaction			
4. Job features that force a man to be isolated from others are eliminated wherever possible.	___	___	___
5. Mechanical pacing is eliminated or minimized.	___	___	___
6. There is a clear line of reporting for relatively isolated personnel.	___	___	___
7. Isolation is counteracted by job enlargement, job rotation, supplementary duties, committee work, etc.	___	___	___
Complexity-Interest			
8. Human engineering has been used to simplify operator tasks and to reduce opportunities for error.	___	___	___
9. Where tasks cannot be combined, job rotation or task variation is employed to increase interest.	___	___	___

	Yes	No	N/A
Group Size and Stability			
10. The size of the group is minimum consistent with the work to be performed.			
11. The supervisor can adequately handle a group of this size.	___	___	___
12. Steps have been taken or procedures developed to minimize sudden increases or decreases in the group's size.	___	___	___
13. Flexibility is provided so that workload increases can be handled by mechanization, methods changes, refresher training, etc., requiring little or no increase in group size.	___	___	___
14. If the group is large, the supervisor is relieved of certain duties or is given assistance.	___	___	___
Combining Groups Into Systems			
Vertical Dimension			
15. Supervisory job duties are so designed that unnecessary levels of supervision are eliminated.	___	___	___
16. Large groups are accommodated by a supervisory partnership, thereby eliminating the need for a separate group.	___	___	___
Horizontal Dimension			
17. Fracturing of groups into several subgroups is avoided by methods changes or job enlargement.	___	___	___
18. Instances of overlapping responsibility and authority are eliminated or reduced.	___	___	___

	Yes	No	N/A
19. A single group reports to only one supervisor.	___	___	___
20. Each group has clear authority over a given set of functions.	___	___	___
21. If possible, abutting groups are merged to eliminate friction between them.	___	___	___
22. Buffer groups are used to improve aspects of intergroup relations, if necessary.	___	___	___

CHECKLIST
FOR
MAN-MACHINE DYNAMICS[1]

The task of assigning functions to men and machines does not readily lend itself to checklist evaluation. This checklist therefore covers only design factors in closed-loop systems and factors affecting human time lags.

	Yes	No	N/A
Closed-Loop Systems			
Pursuit and Compensatory Displays			
1. For pursuit displays, the display is sufficiently large and the background sufficiently structured that movement of both actual and desired output indications is easily seen.	___	___	___
2. Pursuit displays are used when the course contains high frequencies, the system is of zero-order control, or the operator must know the actual output and not just error.	___	___	___
3. A compensatory display is used when the system is quickened or aided, or the display must be kept small, but the output range is large and/or the precision requirements are high.	___	___	___
Intermittent Displays			
4. Inputs shown on the display are simple in nature and the operator need not respond to the inputs quickly and precisely.	___	___	___
5. Anticipatory information is provided by the display.	___	___	___

[1]Adapted from: Ely, J. H., Bowen, H. M. and Orlansky, J. Man-machine dynamics. Chapter VII of the Joint Services Human Engineering Guide to Equipment Design. USAF, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, WADC Technical Report 57-582, November 1957.

	Yes	No	N/A
6. The brightness level of the display is high.	___	___	___
7. All sources of distraction are eliminated.	___	___	___
8. When intermittency results from the operator's having to scan a number of displays, the displays are designed and arranged to minimize the time required to view each display and to shift from one display to another.	___	___	___
9. When signals are displayed intermittently, the duration of each signal is as long as possible and the rate of presentation is as fast as possible.	___	___	___

Machine Dynamics

Note: Items listed below are general statements about machine dynamics. Attributes of machine dynamics all interact with each other and with control resistance in a complex manner. Therefore, it is important to determine the optimum dynamics experimentally, evaluating all attributes concurrently and no one independently.

	Yes	No	N/A
10. Under most conditions, transmission lags are minimized.	___	___	___
11. When the input is complex in nature, the number of integrations is minimized unless the system is aided or quickened.	___	___	___

Aided Tracking

	Yes	No	N/A
12. When the input (desired output) has a constant rate, a constant acceleration, or some constant higher derivative, aiding is used.	___	___	___
13. The number of terms used in aiding exceeds by one the derivative of the input which is constant (e.g., for a constant input rate there are three terms in aiding, viz., position, rate and acceleration; for a constant input acceleration, there are four terms, etc.).	___	___	___

	Yes	No	N/A
14. The aiding constant has been determined empirically for this system.	___	___	___

Quickening

	Yes	No	N/A
15. In a quickened display, as many derivatives as necessary are included, up to the nth derivative in an nth-order control system.	___	___	___
16. Weighting constants for all terms have been determined empirically.	___	___	___
17. If the operator requires information about the actual state of the system he is controlling, auxiliary displays are provided.	___	___	___

Human Time Lags (Reaction Time)

Visual Signals

	Yes	No	N/A
18. Visual signals are of sufficient size, brightness and duration to be easily and obviously seen.	___	___	___
19. Duration of a visual signal is never less than 0.5 second and, where applicable, the signal lasts until the appropriate response has been made.	___	___	___
20. When a task is extended in time, a flashing signal is used (rather than a steady one) because of its greater attention-getting value.			
21. Important signals are placed directly in front of the operator or as close to this position as possible.	___	___	___
22. For flashing signals, the flash rate should be high (at least one cycle per second with the "on" period at least 0.5 second).	___	___	___

	Yes	No	N/A
Auditory Signals			
23. Auditory signals are sufficiently different from the prevailing noise background to be easily and obviously heard.	___	___	___
24. Auditory signal duration is at least 0.5 second and, where applicable, the signal lasts until the appropriate response has been made.	___	___	___
Signal Complexity			
25. The number of signals for a required task is kept to a minimum.	___	___	___
26. When signals are not independent, they are arranged so that the operator can easily see their relationships.	___	___	___
27. Instruments are designed and arranged on a panel to facilitate reading signals.	___	___	___
Signal Rate			
28. Wide variations in signal rate are avoided.	___	___	___
29. If bunching of signals cannot be avoided, some means is provided for the operator to anticipate them and/or the signals remain on until each has been responded to.	___	___	___
30. Signals do not occur at a rate faster than two per second unless some means of anticipation is provided.	___	___	___
31. The use of many signal sources (channels) is avoided (operator performance is better with few channels and a relatively high signal rate than with many channels and a relatively low signal rate).	___	___	___

	Yes	No	N/A
Anticipatory Information			
32. Alerting signals are provided when it is necessary to reduce or eliminate human time lags.	___	___	___
33. Alerting signals precede action signals by from 2.0 to 8.0 seconds for isolated signals and by from 0.3 to 2.0 seconds for signals occurring in sequence.	___	___	___
34. Very short alerting periods (less than 0.1 second) are avoided.	___	___	___
35. Alerting periods are kept as constant as possible.	___	___	___
36. Alerting signals are used to restrict the number of choices whenever possible (e.g., eight action signals can be divided into two groups of four each with a warning signal for each group).	___	___	___
37. Advance information is provided for tracking tasks and/or for bunched signals.	___	___	___
Response Characteristics			
38. Controls which must be activated rapidly are assigned to the right hand.	___	___	___
Operator Conditions			
39. The operator is provided with immediate knowledge of his performance.	___	___	___
40. If possible, the work is self-paced; rigid pacing of a task is avoided.	___	___	___
Watchkeeping Situations			
41. The area in which the signal can appear is restricted.	___	___	___

	Yes	No	N/A
42. The work environment (noise, temperature, humidity, etc.) is maintained at a comfortable level.	___	___	___
43. The observer is not isolated from other individuals nor deprived entirely of incidental stimulation (e.g., smoking, coffee, postural adjustments, minor interruptions).	___	___	___
44. The watch period does not exceed one hour and, when working conditions are poor, does not exceed 30 minutes.	___	___	___
45. When long watch periods are unavoidable, the observer is provided with three- to five-minute rest periods every half hour.	___	___	___
46. Insofar as signal frequency is controllable, it should be kept high.	___	___	___

CHECKLIST
FOR
CONTROLS

	Yes	No	N/A
General			
1. The control requires as few movements as possible.	___	___	___
2. Successive control movements are interrelated (i.e., one movement passes easily into the next).	___	___	___
3. Controls used in rapid sequence have uniform direction of motion.	___	___	___
4. Control movements are consistent for all equipments which one operator uses.	___	___	___
5. The method used to prevent accidental activation of the control, if any, does not increase the time required to operate the control to such an extent that it is unacceptable.	___	___	___
6. Activation of the control does not obscure visual display or control markings such as a potentiometer scale.	___	___	___
Control-Display Relationships			
7. The relationship between the control and its associated visual display is unmistakable in terms of:			
a. The proper control to use.	___	___	___
b. Control movement (i.e., conforms with the controlled display, equipment, or vehicle).	___	___	___
c. Limits of movement of the control.	___	___	___

	Yes	No	N/A
8. Control movement to produce any increase in magnitude, including switching "on," is as follows:			
a. For linear controls: movement forward (i.e., away from the operator), upward or to the right; and for overhead linear controls: movement to the right.	___	___	___
b. For rotary controls: movement clockwise.	___	___	___
9. When there is a direct linkage between the control and display and the indicator moves through more than 180°, a rotary control is used with a rotary display.	___	___	___
10. When using rotary controls with rotary displays:			
a. With moving pointer and stationary dial, clockwise rotation of control results in clockwise rotation of pointer and vice versa.	___	___	___
b. Rotary control is on the concave side of rotary display when display transverses less than a full circle.	___	___	___
11. When using rotary controls with linear displays:			
a. For a moving pointer and fixed scale, with control and display in same plane, the part of the control adjacent to the display moves in the same direction as the moving part of the display.	___	___	___
b. For a moving scale and fixed pointer, with control and display in the same plane, the part of the control adjacent to the display moves in the same direction as the apparent movement of the pointer.	___	___	___
c. Control is not placed above any display or to the left of any vertical display unless it is to be operated by the left hand.	___	___	___

	Yes	No	N/A
12. Linear controls may be used with rotary displays:			
a. When there is no direct linkage between the control and display.	____	____	____
b. When the indicator moves less than 180° and the direction of movement of the indicator and control are parallel.	____	____	____

Positive Indication and Fail-Safe Design

	Yes	No	N/A
13. The control is physically designed to stand abuse, even for unexpected direction of movement (e.g., emergency or panic response).	____	____	____
14. Positive indication is provided that the activation of a control has resulted in equipment response.	____	____	____

Location

	Yes	No	N/A
15. If the operator's task is complex, the controls are distributed so that no one limb is overburdened.	____	____	____
16. Controls requiring rapid, precise settings are assigned to the hands.	____	____	____
17. Controls requiring large amounts of continuous forward applications of force are assigned to the feet.	____	____	____
18. Not more than two controls of even the simplest type are assigned to each foot.	____	____	____

Grouping

	Yes	No	N/A
19. Similar controls are grouped.	____	____	____
20. Relationship between the control and other controls in its associated panel group arrangement is unmistakable in terms of:			

	Yes	No	N/A
a. All controls progress in the same direction.	___	___	___
b. All control pointers are in the same relative position under normal operating conditions.	___	___	___
c. Associated controls are grouped and additionally related by marked outlines if necessary.	___	___	___
Legends			
21. All letters are capitalized except for extended copy which is in capitals and lower case letters.	___	___	___
22. All numbers are Arabic except for special identification.	___	___	___
23. All characters are of the NAMEL or similar style (MIL-C-18012A, MS 33558(ASG)).	___	___	___
24. The use of symbols is avoided but, if symbols are used, they are common meaningful ones.	___	___	___
25. Letters, numbers or other symbols are a minimum of 1/8 inch high.	___	___	___
26. For illuminated letters and numerals on a dark background, the stroke width-to-height ratio is approximately 1:10.	___	___	___
27. For dark letters and numerals on a light or illuminated background, the stroke width-to-height ratio is approximately 1:6.	___	___	___
28. The legend consists of black characters on a light background, except for back-lighted panels where illuminated characters on a dark background are used and energized at all times.	___	___	___
29. Character stroke width is not broken and does not vary in a manner that causes distortion of the critical elements which aid in character identification.	___	___	___

	Yes	No	N/A
30. Separation between characters and words provides optimum readability.	___	___	___
31. The width of numerals is approximately 3/5 of the height, except for the "4" which is one stroke width wider and the "1" which is one stroke width.	___	___	___
32. The width of letters is approximately 3/5 of the height, except for the "I" which is one stroke width and the "M" and "W" which are 4/5 of the letter height.	___	___	___
33. The legend is unique to the particular function served (i. e., the same nomenclature is not used to designate controls with differing functions even though these may be widely separated spatially).	___	___	___
34. Legends are uniform and standardized for ease of recognition (i. e., when controls serving the same functions appear in different places, all are labeled in the same manner).	___	___	___
35. The legend is brief, but not so brief as to be ambiguous.	___	___	___
36. If abbreviations are used, they conform to common usage, or special standards required by this system.	___	___	___
37. The legend is permanently affixed by either etching or embossing, or, for surface legends, a protective coating is applied.	___	___	___
38. The legend is placed on, or sufficiently close to, the control which it identifies so that there is no ambiguity concerning the relationship.	___	___	___
39. The legend is not obscured by parts, components, covers, etc.	___	___	___

	Yes	No	N/A
Coding			
General			
40. All primary and emergency controls are easily identifiable both visually and non-visually.	___	___	___
41. If only one dimension (say slewing control vs. vernier control) is to be coded, only one code dimension is used (i. e., by colors, shapes, or sizes).	___	___	___
42. If two or more dimensions are to be coded (say slewing vs. vernier, and left X vs. right X), the same number of coding dimensions is used.	___	___	___
43. Qualitative codes are used to code qualitative information (i. e., geometric shapes or colors).	___	___	___
44. Quantitative codes are used to code quantitative information (i. e., size, brightness, length, etc.).	___	___	___
Location Coding			
45. The most important and most frequently used controls are located in front of the operator in the optimum manual areas as follows:			
a. Located within comfortable reach, or	___	___	___
b. Between elbow and shoulder height for hand controls.	___	___	___
c. Emergency controls are quickly identified and are located for maximum speed of operation.	___	___	___
d. Controls associated with similar functions are located, when possible, in the same relative position from panel to panel.	___	___	___

	Yes	No	N/A
Shape Coding			
46. Shapes can be discerned both visually and tactually.	___	___	___
47. Only standardized shapes are used.	___	___	___
48. If the coded control presents sharp edges, a clean grasp area is provided.	___	___	___
Size Coding			
49. If the operator cannot compare the sizes of all controls before selecting the proper one, only two or three different sized controls are used in any one group.	___	___	___
50. Controls of the same size are used for performing the same functions on different equipments.	___	___	___
Color Coding			
51. Color coding is used only in white-lighted areas.	___	___	___
52. Control color provides ample contrast with the background.	___	___	___
53. Color coding conforms with established standards of the system.	___	___	___
54. Color coding is limited to the following six colors: white, black, red, yellow, green, blue.	___	___	___

Push Buttons

	Yes	No	N/A
Size			
55. Button size is at least 1/2 inch diameter.	___	___	___
56. For the special case of thumb or heel of hand operation, the button size is at least 3/4 inch diameter.	___	___	___

	Yes	No	N/A
Spacing			
57. Spacing between edges of adjacent push button controls designed for fingertip operation (e.g., on keyboards, keysets, special purpose matrices) is at least 1/4 inch.	___	___	___
58. For the special case of thumb or heel of hand operated push button, spacing between edges of adjacent controls is at least 2 inches.	___	___	___
Displacement			
59. For multiple operation (e.g., on keyboards, keysets, or special purpose matrices) the displacement of all push buttons in the matrix is constant and within 1/8 to 1/2 inch.	___	___	___
60. For non-matrix applications, either thumb or fingertip operated push button control displacement is within 1/8 to 3/4 inch.	___	___	___
Resistance			
61. For multiple operation (e.g., on keyboards, keysets, or special purpose matrices) resistance is at least 5 but not greater than 20 ounces.	___	___	___
62. For non-matrix applications, either thumb or fingertip operated push button control resistance is at least 10 but not greater than 40 ounces.	___	___	___
63. The push button utilizes elastic resistance (aided by a slight amount of sliding friction if possible), starting low and building up rapidly, with a sudden drop to indicate that the control has been activated.	___	___	___
64. The effect of inertial resistance (and viscous damping if applicable) is imperceptible.	___	___	___
65. If possible, an audible click is employed.	___	___	___

	Yes	No	N/A
General			
66. Over-all component design (i.e., enclosure or module, bezel, etc.) economizes panel space.	___	___	___
67. Push button shape is either concave inward to fit the finger or the surface is provided with a high degree of frictional resistance to prevent slipping.	___	___	___
68. Unless design is such that operation of one push button will automatically activate other push buttons, there is little likelihood of accidental activation of more than one push button at a time in a matrix.	___	___	___
69. If accidental activation of a push button will cause a critical situation (e.g., missile destruct, etc.) the push button is well guarded by a channel or cover guard, or is recessed.	___	___	___
70. Alternate action push button stays depressed in one mode.	___	___	___
71. Push button controls are arranged in a horizontal array rather than a vertical array whenever possible.	___	___	___
Toggle Switches			
Size			
72. Control tip diameter (thickness at widest portion of toggle lever) is from 1/8 to 1/2 inch.	___	___	___
73. Lever arm length is from 1/2 to 1 inch.	___	___	___
Spacing			
74. Spacing between adjacent edges of toggle levers mounted in a row is at least 3/4 inch.	___	___	___

	Yes	No	N/A
Displacement			
75. The displacement of toggle lever is sufficient for visual and tactual discrimination in its particular application.	___	___	___
76. For two-position switch, centerline displacement between on-off mode is at least 60 degrees.	___	___	___
77. For three-position switch, centerline displacement between adjacent positions is at least 40 degrees from center.	___	___	___
78. Maximum total displacement for either a two- or three-position switch is 120 degrees.	___	___	___
Resistance			
79. From 10 to 40 ounces of force is required to overcome switch resistance and activate switch.	___	___	___
80. If momentary contact type, spring tension is sufficient to return switch to the null position when force is removed.	___	___	___
81. The toggle switch utilizes elastic resistance which builds up, then decreases as the desired position is approached, so that the control will snap into its position and cannot stay between adjacent positions.	___	___	___
82. The effects of friction and inertia are minimized.	___	___	___
General			
83. If mounted horizontally, it is so only to be consistent with orientation of the controlled function and movement forward or to the right corresponds to "on," "start" or "increase," while motion rearward or to the left corresponds to "off," "stop" or "decrease."	___	___	___

	Yes	No	N/A
84. Rows of toggle switches are mounted in a horizontal (rather than vertical) array to prevent inadvertent activation of the wrong switch.	____	____	____
85. Where several toggle switches of similar appearance are grouped, control discriminability is optimized by increased physical separation, control coding, or the insertion of dissimilar controls between them. This is particularly important for critical controls.	____	____	____
86. Critical toggle switches are provided with a locking device or control guard cover so that at least two discrete operator movements are required to activate the control.	____	____	____
87. An audible click is provided.	____	____	____
88. The control lever is easily grasped and there are no sharp edges.	____	____	____

Rotary Selector Switches

Size

	Yes	No	N/A
89. For bar-type control, the pointer is from 1 to 3 inches in length and at least 1/2 inch wide (except for heavy switchboard applications which require higher torque).	____	____	____
90. For circular control, the knob diameter is from 1 to 4 inches.	____	____	____
91. Pointer or knob grasp depth is at least 1/2 inch (but not more than 3 inches).	____	____	____

Spacing

Spacing between edges of adjacent controls is as follows:

	Yes	No	N/A
92. For one hand at a time randomly selecting adjacent selector switch controls, at least 1 inch spacing is maintained between control knobs at their closest point.	___	___	___
93. For two hands simultaneously selecting adjacent selector switch controls, at least 3 inch spacing is maintained between control knobs at their closest point.	___	___	___
<u>Displacement</u>			
94. For red-lighted areas (where essentially a non-visual positioning requirement exists), displacement between adjacent detents is at least 30 degrees or 1/4 inch, whichever is greater (i.e., index marks are arranged on at least a 1-inch diameter scale).	___	___	___
95. For areas always white lighted (i.e., visual positioning possible), displacement between adjacent detents is at least 15 degrees or 1/4 inch, whichever is greater (i.e., for 15-degree displacement, index marks are arranged on at least a 1-3/4 inch diameter).	___	___	___
96. Maximum displacement between detents is 45 degrees except where contrast size or power requirements necessitate wider spacing, in which case up to 90 degrees is acceptable (i.e., switchboards, etc.).	___	___	___
<u>Resistance</u>			
97. Elastic resistance requires from 1 to 6 inch-pounds of rotational torque to move the selector switch out of detent position.	___	___	___
98. Elastic resistance builds up, then decreases as each detent is approached, so that the control will fall into each detent and cannot stop between adjacent positions.	___	___	___

	Yes	No	N/A
99. Friction and inertia are minimized in control design.	___	___	___

General

	Yes	No	N/A
100. The selector switch has a fixed scale with a moving pointer.	___	___	___
101. Bar-type or parallel-sided knob is used except where ganged selector controls are used because of space limitations.	___	___	___
102. If skirts are used on the control knob, there is a bar-type or parallel-sided grasp area provided which conforms with the above size requirements.	___	___	___
103. The knob pointer is close to the scale index mark to minimize parallax.	___	___	___
104. All knobs are black except in red-lighted areas where all knobs are gray.	___	___	___
105. Pointer and index marks and characters have sufficient contrast with their backgrounds to be readily visible under all expected conditions of illumination.	___	___	___
106. Where several knobs of similar appearance are grouped, control discriminability is optimized by increased physical separation, control coding, or the insertion of dissimilar controls between them.	___	___	___
107. The grasp area on the control knob is provided with a rough surface finish to prevent slipping.	___	___	___
108. For critical control whose operation beyond a given point might damage equipment, two discrete operator movements are required. Furthermore, they are limited to one-step-at-a-time movement requiring additional discrete movements to free them for further manipulation.	___	___	___

	Yes	No	N/A
109. Detents are provided at each control setting.	___	___	___
110. Where a selector switch has more than 4 positions and multiturn operation is not required, start and end stops are provided (i.e., two positions in addition to the number of active mode settings).	___	___	___
111. Control stop resistance is capable of withstanding 25 inch-pounds of rotational torque without damage to the control.	___	___	___
112. If possible, there is a gap larger than index displacement between the beginning and end of the circular scale.	___	___	___

Knobs

Size

113. For fingertip grasp, knob dimensions are as follows:			
a. Knob diameter is minimum 3/8 inch, maximum 4 inches.	___	___	___
b. Knob depth or grasp area is minimum 1/2 inch, maximum 1 inch.	___	___	___
114. For palm grasp (or door knob type knob) dimensions are as follows: knob diameter is minimum 1-1/2 inches, maximum 3 inches.	___	___	___
115. For bar grasp, thumb and fingers encircled about a circular bar, knob or hand-grip dimensions are as follows:			
a. Control diameter is minimum 1 inch, maximum 3 inches.	___	___	___
b. Control length is at least 3 inches.	___	___	___

	Yes	No	N/A

116. Minimum dimensions for concentric (or ganged) knobs are as follows (if only two knobs are ganged, use top and middle dimensions):

	Diameter	Height
Top knob	1/2 inch	3/4 inch
Middle knob	1-3/4 inch	3/4 inch
Bottom knob	3 inch	1/4 inch

Concentric knob dimensions conform with above minimum requirements. ___ ___ ___

Spacing

117. For fingertip operation, spacing between edges of adjacent controls is at least 3/4 inch. ___ ___ ___

118. For hand grasp operation, spacing between edges of adjacent controls is at least 2 inches. ___ ___ ___

119. For adjacent knobs which require simultaneous operation, spacing between edges is at least 3 inches. ___ ___ ___

Displacement

120. The optimum control/display ratio is employed. Generally, for fine adjustments there is between 60 and 80 degrees movement from just detectable misalignment in one direction to just detectable misalignment in the other. For gross adjustments the optimum control/display ratio cannot be given for all controls, but generally, small control movements correspond to large display movements. ___ ___ ___

121. A knob-crank combination is employed where the task involves large slewing movement plus fine adjustment. ___ ___ ___

	Yes	No	N/A
Resistance			
122. Maximum resistance for fingertip operation of 1 inch (or less) diameter knobs is 4-1/2 inch-ounces.	___	___	___
123. Maximum resistance for fingertip operation of knobs over 1 inch diameter is 6 inch-ounces.	___	___	___
General			
124. Control resistance is applied evenly throughout 360 degree rotation (i.e., there are no "sticky spots," detents, etc.).	___	___	___
125. If skirts are used on the knob, an adequate grasp area which conforms with above size requirements is provided.	___	___	___
126. If a pointer or index mark is used on the continuous control, it is close to the scale index mark to minimize parallax.	___	___	___
127. Index numbers are not obscured when hand is on the control knob.	___	___	___
128. All knobs are black, except in red-lighted areas where all knobs are gray.	___	___	___
129. Where several knobs of similar appearance are grouped, control discriminability is optimized by increased physical separation, control coding, or the insertion of dissimilar controls.	___	___	___
130. Pointer and index marks and characters have sufficient contrast with their backgrounds to be readily visible under all expected conditions of illumination.	___	___	___
131. The grasp area on the control knob is provided with a rough surface finish to prevent slipping (knobs over 1 inch diameter are serrated).	___	___	___

	Yes	No	N/A
132. If the control is not designed for multiturn operation, there is a gap larger than the regular index displacement between the beginning and end of the circular scale, and start and end stops are provided.	___	___	___

Cranks

Size

133. Crank radius for minimum load (under 5 lbs/in) and high rpm rate (up to 275 rpm) is optimum consistent with performance requirements and within the following recommended radius values: *minimum* 1/2 inch, *maximum* 4-1/2 inches.	___	___	___
134. Crank radius for heavy loads is optimum consistent with performance requirements as follows:			
a. *For under 175 rpm rate and heavy load* (between 6 and 15 lbs/in) radius is within the following recommended values: minimum 5 inches, maximum 8 inches.	___	___	___
b. For extra heavy loads, maximum radius is 20 inches.	___	___	___

Spacing

135. Spacing between the outside edge of the crank handle and any other obstruction is at least 3 inches.	___	___	___

Displacement

136. The crank is used for tasks requiring at least two rotations of control movement.	___	___	___
137. The optimum control/display ratio is employed (see knob displacement above).	___	___	___

	Yes	No	N/A
138. For tasks involving large slewing movements plus small fine adjustments (less than 1/2 rotation) the crank is mounted on a knob which conforms with the above requirements for knobs.	___	___	___

Resistance

139. For small cranks (less than 3-1/2 inch radius) where high speed operation (rapid, steady timing up to 275 rpm) is required, resistance is optimum consistent with performance requirements and within the following limits: minimum 2 pounds, maximum 5 pounds.	___	___	___
140. For large cranks (5 - 8 inch radius) where high speed operation (rapid, steady turning) is required, resistance is optimum consistent with performance requirements and within the following limits: minimum 5 pounds, maximum 10 pounds.	___	___	___
141. If precise settings are required (adjusting between 1/2 and 1 rotation) resistance is optimum consistent with performance requirements and within the following limits: minimum 2-1/2 pounds, maximum 8 pounds.	___	___	___
142. For cranks that operate at low rpm (3 - 10 rpm) frictional resistance is minimized at between 2 - 3 inch-pounds.	___	___	___
143. Sufficient inertial resistance is employed to aid performance in rotating crank handles at a constant rate, particularly for small cranks and at low rates (i. e., small cranks are heavy in proportion to their size).	___	___	___
144. The grip handle is free to rotate around its shaft.	___	___	___

	Yes	No	N/A
Handwheels			
Size			
145. Handwheel dimensions are optimum for performance requirements and are within the following limits: minimum 7 inches diameter, maximum (for hands placed at each end of the diameter) 21 inches. (If operator does not have to hold handwheel at opposite ends of diameter, no limitation-optimum diameter set by operator performance.)	___	___	___
146. Cross-sectional diameter of handwheel rim is at least 3/4 inch but not greater than 2 inches.	___	___	___
Spacing			
147. Handwheel is located so that there is at least 3 inches between the outer edge and the nearest obstruction.	___	___	___
Displacement			
148. If applicable, the optimum control/display ratio is employed.	___	___	___
149. When shifting hand position is undesirable and optimum control/display ratio is not hindered, required displacement is between 90 and 120 degrees.	___	___	___
150. When handwheel movement is limited to small areas, the optimum control/display ratio is met by using a large diameter handwheel (over 15-inch diameter).	___	___	___
Resistance			
151. Handwheel resistance is optimum for performance requirements and is within the following limits: minimum 5 inch-pounds, maximum (one hand operation) 30 inch-pounds, maximum (two hand operation) 50 inch-pounds.	___	___	___

	Yes	No	N/A
152. If operation requires movement through small areas, inertial resistance is minimized (i. e., a light handwheel is used).	___	___	___
153. If operation requires multirotational movement, the handwheel employs inertia (and a crankhandle may be attached when large displacements must be made rapidly).	___	___	___
154. Indentations are built into the handwheel rim to aid in holding it.	___	___	___

Levers (Under 6 Inches)

Size

	Yes	No	N/A
155. For fingertip grasp, knob diameter is between 1/2 inch and 1 inch.	___	___	___
156. For spheroid or hand grasps, knob diameter is between 1-1/2 inches and 3 inches.	___	___	___
157. The lever or tracking control does not protrude from the panel surface more than 6 inches.	___	___	___

Spacing

	Yes	No	N/A
158. For one hand, random operation of a lever, at least 2 inches separation between the outer edge of the lever at maximum displacement and any obstruction is maintained.	___	___	___
159. For two hands, simultaneously operating adjacent levers, at least 3 inches separation is maintained.	___	___	___
160. For the special case where a group of levers are used simultaneously by the same hand, their maximum separation (between outside edges of tip) is 6 inches.	___	___	___

	Yes	No	N/A
Displacement			
161. For small joystick tracking controls, on table or desk-top installation, the control/display ratio does not require more than 60-degree displacement from the vertical or null position in any direction.	___	___	___
162. The tip of the tracking control moves at least 2-1/2, but not more than 4 times as fast as the controlled function on the display screen. (This is for either linear or non-linear controls.)	___	___	___
163. Where space limitations prohibit the above movement requirements, a rigid or pressure type control is used.	___	___	___
Resistance			
Note: No exact amount of control resistance can be established to cover all cases, because the controlled function will determine the required resistance for optimum performance.			
164. For any guidance joystick type lever controls, elastic resistance which increases non-linearly is used to furnish the operator with sufficient "stick feel" to aid in his tracking task.	___	___	___
165. There is no detent pressure employed on a continuous tracking joystick type control, but sufficient elastic resistance is incorporated to return the control to the null position when operating pressure is removed.	___	___	___
166. For discrete position lever controls, either a locking slot or a detent is provided at each control position.	___	___	___

	Yes	No	N/A
167. Discrete position lever control employs static and sliding friction (dry frictional resistance) which decreases sharply to a constant value when the control starts to move and permits movement between positions which are smooth and continuous (i.e., no control "freeze up" or binding).	___	___	___
168. Discrete position lever control employs a detent or sufficient static friction to allow the control position to be "felt" without disturbing it.	___	___	___
169. Operator performance is not hampered by excessive control resistance.	___	___	___
General			
170. Support is provided for the body part being used in making fine adjustments with small joystick or other lever type controls as follows:			
a. For finger movements, the wrist is supported.	___	___	___
b. For small hand movements, the forearm is supported.	___	___	___
c. For large hand movements, the elbow is supported.	___	___	___
171. Where very fine adjustments with a small joystick are required, and the control could be grasped "pencil-style" below the tip rather than on it, the pivot point is recessed below the surface on which the wrist rests.	___	___	___
Foot Controls			
Size			
172. For foot activated push button, the effective button diameter is at least 1/2 inch.	___	___	___

	Yes	No	N/A
173. For control using a pedal, pedal size is at least 1 by 4 inches.	___	___	___
Spacing			
174. Spacing between edges of adjacent foot push buttons or pedals is at least 4 inches.	___	___	___
Displacement			
175. For operator expected to wear normal or light footwear, displacement is at least 1/4 inch.	___	___	___
176. For operator expected to wear heavy footwear, displacement is at least 1 inch.	___	___	___
177. For control operated by ankle flexion only, maximum displacement is 2-1/2 inches.	___	___	___
178. For control operated by leg movement, maximum displacement is 4 inches for push button and 7 inches for pedal.	___	___	___
Resistance			
179. When foot does not rest on the control, resistance is at least 4 pounds.	___	___	___
180. When foot may rest on the control, resistance is at least 10 pounds.	___	___	___
181. For normal operation with foot resting or not resting on control, maximum resistance is under 20 pounds.	___	___	___
182. Foot push button or pedal uses elastic resistance (aided by static and sliding friction) and will return to the null position when force is removed.	___	___	___

	Yes	No	N/A
183. Foot push button resistance starts low, builds up rapidly, then drops suddenly to indicate that the control has been activated.	___	___	___
184. The effect of inertial resistance (and viscous damping if applicable) is imperceptible.	___	___	___
<u>General</u>			
185. The control is designed for toe operation (by the ball of the foot) rather than heel operation.	___	___	___
186. Where space permits, a pedal hinged at the heel is placed over the push button to aid in locating and activating the control.	___	___	___
187. If possible, an audible click is provided for foot push buttons.	___	___	___

CHECKLIST
FOR
DISPLAYS

Information	Yes	No	N/A
1. Information presented is necessary for the decisions or actions required of the operator.	___	___	___
2. Information is presented in the most immediately meaningful form (i.e., no interpretation or decoding is required).	___	___	___
3. Information is displayed to the accuracy required by the decisions or actions of the operator, and preferably no more accurately than required.	___	___	___
4. If scale interpolation is required, it does not introduce a probability for operator errors which are greater than the operator's task permits.	___	___	___
5. Information for different types of activities (e.g., operation and maintenance) is not combined unless the activities require the same information.	___	___	___
6. Information is current (i.e., lag is minimized).	___	___	___
7. Failure in the unit is clearly shown or the operator is otherwise warned.	___	___	___
General Design			
8. Over-all display area is minimum consistent with legibility at the required reading distance.	___	___	___
9. The display can be read easily from the expected or normal locations of all operators who require the information.	___	___	___

	Yes	No	N/A
10. Company trade names or other markings irrelevant to the display (e.g., patent numbers) do not appear on the display in a manner that is distracting.	___	___	___
11. When the operator must monitor and/or perform a sequence of operations, the displays are arranged in the actual order of events.	___	___	___
12. When no definite sequence of operations determines the order of events, the displays are grouped by function.	___	___	___
13. The relationship between the display and its associated controls is unmistakable in terms of:			
a. The proper control to use.	___	___	___
b. The direction of movement of the control.	___	___	___
c. The rate and limits of movement of the control.	___	___	___
14. The display is designed to minimize the problem of parallax within the normal visual axis of the operator.	___	___	___

<u>Illumination</u>

	Yes	No	N/A
15. Contrast ratio is at least 5:1 between pointers, markings, and characters and the background under all expected conditions of illumination.	___	___	___
16. If the instrument has a movable pointer, the pointer is well illuminated at all positions.	___	___	___
17. Brightness is uniform over the display face.	___	___	___
18. Glare does not interfere with the interpretation of the display regardless of the display location in the work area.	___	___	___

	Yes	No	N/A
19. If lighting cannot be controlled to eliminate reflection on the display, then every effort is made to reduce its effect.	___	___	___

Coding

20. Zone markings are employed as necessary to indicate the various zones of operating conditions (e.g., desirable operating range, danger-lower limit, danger-upper limit, caution, undesirable-inefficient, etc.).	___	___	___
21. If zone markings are employed:			
a. Markings are located such that they do not obscure the scale or the scale numbers.	___	___	___
b. Color coding is employed in white ambient areas <u>only</u> and is consistent with the recommended color coding for the entire system.	___	___	___
c. Shape coding is employed in red ambient areas.	___	___	___
d. No more than five code steps are used.	___	___	___
22. If the indicator is located within a group of dials, the pointer is oriented in the same relative position with respect to the other dials of the group (i.e., position code the pointer).	___	___	___
23. Color coding is consistent with that specified for the system (generally, red requires immediate action; yellow, caution and monitor; green, proceed normally; white, combine information to determine required action; blue, command to take action).	___	___	___
24. Indicator lights used for the most critical conditions are significantly different from the other indicator lights (i.e., in color, brightness or size).	___	___	___

	Yes	No	N/A
25. Indicator light is capable of providing flashing red for emergency or malfunction in low-level, red-lighted areas.	___	___	___

Legends

	Yes	No	N/A
26. All letters are capitalized except for extended copy which is in capitals and lower case letters.	___	___	___
27. All numbers are Arabic except for special identification.	___	___	___
28. All characters are of the NAMEL or similar style (MIL-C-18012A, MS 33558(ASG)).	___	___	___
29. The use of symbols is avoided, but, if symbols are used, they are common meaningful ones.	___	___	___
30. Letters, numbers or other symbols are a minimum of 1/8 inch high.	___	___	___
31. For illuminated characters on a dark background, the stroke width to height ratio is approximately 1:10.	___	___	___
32. For dark characters on an illuminated background, the stroke width to height ratio is approximately 1:6.	___	___	___
33. Character stroke width is not broken and does not vary in a manner that causes distortion of the critical elements which aid in character identification.	___	___	___
34. Separation between characters in a sequence is constant and not more than the character height.	___	___	___
35. For numerals over 3/16" in height, the width of the numeral is approximately 3/5 of its height except for the "4" which is one stroke width wider and the "1" which is one stroke width.	___	___	___

	Yes	No	N/A
36. For letters over 3/16" in height, the width of the letter is approximately 3/5 of its height except for the "I" which is one stroke width and the "M" and "W" which are 4/5 of letter height.	___	___	___
37. For numerals and letters under 3/16" in height, the height to width ratio is 1:1.	___	___	___
38. Indicators are labeled according to function.	___	___	___
39. Legends are unique to the particular function served (i.e., the same nomenclature is not used to designate indicators with differing functions even though these may be widely separated spatially).	___	___	___
40. Legends are uniform and standardized for ease of recognition (i.e., when indicators serving the same function appear in different places, all are labeled in the same manner).	___	___	___
41. Legends are brief, but not so brief as to be ambiguous.	___	___	___
42. If abbreviations are used, they conform to common usage.	___	___	___
43. Legends are permanently affixed by either etching or embossing, or, if surface legends must be used, decals with a protective coating or embossed metal identification "metalcals" are used.	___	___	___
44. Legends are not obscured by parts, components, moisture proofing covers, etc.	___	___	___
45. The legend is placed on, or sufficiently close to, the display (preferably above the display) which it identifies so that there is no ambiguity concerning the relationship.	___	___	___

	Yes	No	N/A
46. Legends consist of black characters on a light background, except for back-lighted panels where illuminated characters on a dark background are used.	___	___	___
47. In low-level, red-lighted areas, legends are illuminated and energized at all times.	___	___	___

Dials, Gages and Meters

48. Changes in indication are easy to detect both in magnitude and direction.	___	___	___
49. The operator is able to make a qualitative or check reading of the display when it is in the periphery of his visual field.	___	___	___
50. The relationship between this dial and other dials in its associated panel grouping is similar in terms of:			
a. Scale breakdown and numerical progression.	___	___	___
b. Values on all dials increase in the same direction.	___	___	___
c. Under normal operating conditions, all pointers are in the same relative position.	___	___	___
51. The scale numbers increase in a regular and obvious sequence.	___	___	___
52. The smallest readable scale division is not finer than the probable error which is inherent in the metering apparatus.	___	___	___
53. The scale graduation interval (distance between graduation marks) is approximately equal to the degree of accuracy required in reading the indicator.	___	___	___
54. All major scale divisions are numbered.	___	___	___

	Yes	No	N/A
55. The pointer extends to, but does not cover, scale graduation marks.	___	___	___
56. If possible, numerals appear on the opposite side of the graduation marks from the pointer so that the pointer does not cover them in reading.	___	___	___
57. The dial face is designed as simply as possible and only information which is usable by the operator appears on the display (i.e., manufacturer's name, etc., do not appear).	___	___	___

Circular Scales: Moving Pointer, Fixed Scale

	Yes	No	N/A
58. The circular scale numbers increase in a clockwise direction (i.e., clockwise pointer movement indicates an increase in magnitude).	___	___	___
59. The pointer moves clockwise as a result of moving an associated lever or switch clockwise, upward, forward, or to the right.	___	___	___
60. Critical regions in the circular scale are assigned to the 9, 12, 3 or 6 o'clock position.	___	___	___
61. The circular scale zero is located near the bottom of the dial except when zero calibration or check reading is required.	___	___	___
62. If the scale is to be calibrated positively and negatively from zero, zero calibrations are set in the 9 or 12 o'clock position; for multirevolution indicators the zero is at the 12 o'clock position.	___	___	___
63. Except on multirevolution instruments, there is a scale break of at least 1-1/2 major divisions at the end of the scale.	___	___	___
64. Numerals are arranged so that they are upright in all positions.	___	___	___

	Yes	No	N/A
Circular Scales: Fixed Pointer, Moving Scale			
65. Counterclockwise scale movement indicates increase in magnitude.	___	___	___
66. Pointer or lubber line is at 12 o'clock for right-left information.	___	___	___
67. Pointer or lubber line is at 9 o'clock for up-down information.	___	___	___
68. Open window is large enough to permit at least one numbered graduation to appear at each side of any setting. (This will assure that at least two numbers are visible at all times for reference purposes.)	___	___	___
69. When numerals on a dial move past an open window, they are arranged so that they appear upright at the window opening.	___	___	___
Linear Scales: Moving Pointer, Fixed Scale			
70. Movement of the pointer upward or to the right indicates increase in magnitude.	___	___	___
71. Pointer moves upward or to the right as a result of a clockwise or upward movement of an associated control.	___	___	___
72. Pointer is to the right of vertical scales and at the bottom of horizontal scales.	___	___	___
73. Critical markings are not located on either end of the straight scale.	___	___	___
74. Numerals are arranged so that they are upright in all positions.	___	___	___
Linear Scales: Fixed Pointer, Moving Scale			
75. Numerals increase from bottom to top or from left to right.	___	___	___

	Yes	No	N/A
76. Scale moves down or to the left (increase) when:	___	___	___
a. Associated knob or crank is moved clockwise.	___	___	___
b. Associated lever is moved forward, upward or to the right, or the vehicle or component moves up or to the right.	___	___	___
77. Numerals are arranged so that they are upright in all positions.	___	___	___

Indicator Lights

	Yes	No	N/A
78. All indicator lights on any one panel are on the same plane and/or are mounted flush with the surface of the panel.	___	___	___
79. Flash rate for warning indicator lights is between 3 and 5 flashes per second, with "on" time approximately equal to "off" time.	___	___	___
80. Brightness level is approximately the same for all colors, except for red which is greater when used for indications of critical conditions.	___	___	___

Unit Character Displays

	Yes	No	N/A
81. Multicharacter displays read sequentially from left to right rather than vertically.	___	___	___
82. All characters are displayed on the same plane and as close to the plane of the panel surface as possible, thereby providing maximum viewing angle and minimizing parallax and shadow.	___	___	___
83. Deenergized display characters are not visible.	___	___	___
84. If the background area around each character is small, the display bezel is the same color as the background to increase effective background area.	___	___	___

	Yes	No	N/A
Counters			
85. The counter is oriented to read from left to right.			
86. All characters are displayed on the same plane and as close to the plane of the panel surface as possible, thereby providing maximum viewing angle and minimizing parallax and shadow.			
87. Counter drums used to display an alternate function are covered when that function is not in use.			
88. The number of significant digits displayed does not infer accuracy beyond the inherent accuracy of the function being displayed.			
89. Zeros (not decimal multipliers) are used on the extreme right or left of the counter to define the order of magnitude of the readout.			
90. For discrete information, numbers snap into position.			
91. For discrete information, only the digits to be read out (and no portion of adjacent digits) are visible from the expected viewing position of the operator; for continuous information, preceding and following digits are visible.			
92. Maximum number speed is not greater than two per second when numbers must be read in motion.			
93. If the counter requires regular resetting, this is done automatically.			

CHECKLIST
FOR
TRAINING EQUIPMENT*

The purpose of training equipment is one or more of the following:

1. To demonstrate cause-effect relationships.
2. To demonstrate equipment operations.
3. To demonstrate operator controlled inputs.
4. To demonstrate maintenance procedures.
5. To measure operator and/or equipment performance.
6. To train instructors.
7. To demonstrate team performance.

This checklist is designed to assure the effective accomplishment of the appropriate purpose of the training equipment.

	Yes	No	N/A
Operator Controls			
1. All controls in the operational equipment are duplicated in the training equipment.	___	___	___
2. The controls are coded, for purpose of training, with respect to:			
a. Color	___	___	___
b. Shape and size.	___	___	___
c. Relative position.	___	___	___
3. The controls in the operational equipment which are absent or do not operate in the trainer are not necessary for adequate training.	___	___	___

*This checklist is derived from material presented in Miller, R. B. Human engineering design schedule for training equipment. USAF, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, WADC TR 53-138, 1953.

	Yes	No	N/A
4. The direction of motion of controls in the trainer is identical to that in the operational equipment.			
5. The extent of movement of controls in the trainer is identical to that in the operational equipment.			
6. The control forces in the trainer are identical to those in the operational equipment:			
a. Starting friction.			
b. Stickiness.			
c. Damping.			
d. Feedback pressure.			
e. Free play.			
<u>Displays</u>			
7. All displays in the operational equipment also appear in the trainer.			
8. Displays in the trainer which are different from those in the operational equipment do not affect training value.			
9. Illumination can be controlled, as in the operational situation.			
10. Pointers and cursors move as in the operational equipment.			
<u>Control Display Interactions</u>			
11. Direction of control display movement matches that of the operational equipment.			

	Yes	No	N/A
12. The ranges of movement of controls and displays duplicate the operational equipment.	____	____	____
13. In the trainer, a given amount of control movement produces the same amount of display movement as in the operational equipment.	____	____	____
14. The sensitivity of control movement in the trainer matches that of the operational equipment.	____	____	____
15. Irrelevant control display effects (noise) equal that found in operational conditions.	____	____	____
16. Time delays between control activation and display response are realistic.	____	____	____
17. The design characteristics of the trainer do not provide spurious cues (i.e., *information not* present in the real situation) to the student.	____	____	____

<u>Representation of the Field Situation</u>

	Yes	No	N/A
18. A variety of field situations can be programmed.	____	____	____
19. The field situations are typical.	____	____	____
20. The field situations created for purpose of the trainer vary in:			
a. Complexity.	____	____	____
b. Duration.	____	____	____
c. Number.	____	____	____
d. Rate of change.	____	____	____
e. Order of presentation.	____	____	____
f. Distracting (typical field) conditions.	____	____	____

	Yes	No	N/A
g. Capability of being repeated.	___	___	___
h. Typical breakdowns of information.	___	___	___
Scoring and Error Analysis			
21. The variables which are scored in the trainer measure successful performance in the field.	___	___	___
22. The equipment can provide scores for:			
a. The student's ability to identify cues correctly.	___	___	___
b. The student's ability to distinguish cues from noise.	___	___	___
c. The student's ability to scan all information.	___	___	___
23. The equipment provides a measure of effectiveness of decisions made by the student.	___	___	___
24. The equipment provides measures of certain control motions:			
a. Movement of proper control.	___	___	___
b. Failure to move proper control.	___	___	___
c. Improper combinations of control movements.	___	___	___
d. Improper sequences of control movements.	___	___	___
e. Direction of control movement.	___	___	___
f. Magnitude of control movement.	___	___	___
g. Temporal aspect of control movement.	___	___	___
25. The sensitivity and range of scoring can be varied as student performance improves.	___	___	___

	Yes	No	N/A
26. The scores are reliable (i.e., repeatable).	___	___	___
27. A permanent record is provided.	___	___	___
Motivation of the Student			
28. The trainer fits into the training curriculum because it challenges the student.	___	___	___
29. The trainer does not distract the student from the need to train (because it is noisy, not "real" enough, etc.).	___	___	___
Practice			
30. A skilled person can use the equipment to demonstrate an adequate performance.	___	___	___
31. The student is afforded an opportunity to learn correct nomenclature.	___	___	___
32. The student can practice locating specific controls and displays.	___	___	___
33. The presence and magnitude of essential cues and background noise can be varied for purpose of practice.	___	___	___
34. Significant tasks can be practiced independently with knowledge of results.	___	___	___
35. The training situation provides realistic practice by means of malfunctions, errors, incorrect procedures.	___	___	___
36. Where several operators are involved, coordination of effort can be practiced.	___	___	___
37. The scoring range or difficulty level of problems permits overlearning.	___	___	___

	Yes	No	N/A
38. The reliability, capacity, and number of pieces of equipment permit an appropriate amount of training time for all students.	____	____	____
39. The training equipment permits practice in the transition from one model of operational equipment to another.	____	____	____
40. Correct operating procedures can be practiced and measured.	____	____	____

Facilities for the Instructor

	Yes	No	N/A
41. The instructor can check that the training equipment is operating correctly:			
a. The checkout is simple and rapid.	____	____	____
b. Calibration and adjustment can easily be accomplished.	____	____	____
c. Warm up and starting are simple and rapid.	____	____	____
42. The instructor's operating procedures are simple, automatic and easy for him to learn.	____	____	____
43. Simultaneous or sequential activities are simple to control.	____	____	____
44. The difficulty-level of problem tasks may be readily altered.	____	____	____
45. The complexity of the problem faced by the student can readily be modified by the instructor.	____	____	____
46. The amount of information given to the student can be varied by the instructor.	____	____	____
47. The time allowed the student for making decisions can be varied by the instructor.	____	____	____

	Yes	No	N/A
48. The number and type of control motions required by the student can be varied by the instructor.	____	____	____
49. The instructor has a facility for observing the goodness of the student's performance:			
a. Rapidly.	____	____	____
b. It is readily interpreted.	____	____	____
c. It contains relevant information.	____	____	____
50. The instructor has facilities for transmitting information about performance to the student:			
a. Easily and rapidly.	____	____	____
b. Without disrupting the student.	____	____	____
c. At significant points in task performance.	____	____	____
d. About over-all task success.	____	____	____
51. The instructor's controls conform to sound human engineering principles with respect to:			
a. Accessibility.	____	____	____
b. Placement with respect to displays.	____	____	____
c. Functional grouping.	____	____	____
d. Movement stereotypes.	____	____	____
e. Tandem linkages where appropriate.	____	____	____
f. Fewness in number.	____	____	____

CHECKLIST
FOR
EXPERIMENTAL METHODS

A test may be conducted for one or more of the following purposes:

1. To obtain basic data for general application.
2. To obtain data for application to a specific system.
3. To demonstrate the effectiveness of a design concept.
4. To determine normal expected level of performance.

This checklist presents the basic items the experimenter should consider in conducting his test to accomplish the appropriate test purpose.

	Yes	No	N/A
1. Handbooks or other publications have been checked for availability of relevant data.	____	____	____
2. The cost of the test is proportional to the degree of uncertainty in existing data.	____	____	____
3. The range of independent variables is reasonable, considering the purpose of the test.	____	____	____
4. All anticipated sources of variability are either controlled or accurately measured.	____	____	____
5. A short preliminary test has been conducted if such a test would help to identify pertinent variables.	____	____	____
6. Artificialities due to the presence of observers or recording instruments have been eliminated from (or accounted for in) the test situation.	____	____	____
7. Giving the subjects undesirable foreknowledge of the test situation has been avoided.	____	____	____
8. The operation being tested is significant in terms of its contribution to system effectiveness.	____	____	____

	Yes	No	N/A
9. The dependent variables (measures) are appropriate to the way the system is actually to be used.	___	___	___
10. If learning time is an important effect, it has been included in the measurement.	___	___	___
11. If learning time is not to be measured, enough preliminary trials have been given to eliminate the learning effect.	___	___	___
12. If performance time is important, the practical minimum time (if any) below which any further reduction is of no practical value has been determined.	___	___	___
13. If accuracy is important, the practical tolerable error, if any, has been determined.	___	___	___
14. The tasks set in the trials are difficult enough to demonstrate differences between experimental and control conditions.	___	___	___
15. If they would be of value, preference judgments have been obtained.	___	___	___
16. If a record of voice communications would help in interpreting results, this has been provided for.	___	___	___
17. The order of presentation for important variables has been counterbalanced or randomized.	___	___	___
18. The subjects have been selected from a representative sample of the user population.	___	___	___
19. If different groups of subjects are used for different conditions, they are matched for experience, skill, intelligence, age, etc.	___	___	___

	Yes	No	N/A
20. The number of observations (trials or subjects) is sufficient in view of the size of the variable error.	___	___	___
21. The form of statistical analysis of data has been determined before the test is designed and run.	___	___	___
22. The instructions to the subjects are understandable and consistent for all subjects.	___	___	___
23. Steps have been taken to insure that the test subjects are motivated to perform well.	___	___	___
24. In interpreting results, experimenter determines whether:			
a. Scores are absolutely valid or if they reflect only relative differences between conditions.	___	___	___
b. Results are practically significant.	___	___	___
c. Results are statistically significant.	___	___	___
d. Results satisfy test objectives.	___	___	___
25. Results are qualified, if necessary, because of limitations of the test, uncontrolled variables, or other contaminating factors.	___	___	___

PART IV. BIOGRAPHICAL INFORMATION ON LECTURERS

ROBERT T. ECKENRODE
Program Director

Education:

B.Ch.E., Villanova University, 1951.

Post-graduate study in engineering, Drexel Institute of Technology, 1952-53.

Post-graduate study in experimental psychology:

University of Pennsylvania, 1954-56.
Fordham University, 1959-present.

General Experience:

At Dunlap and Associates, Inc., 1956 to present:

Currently directs all human engineering and systems analysis on HAWK I and Second-Generation HAWK weapon systems, and on the Airborne Missile Control System for the Sparrow III missile in the F4H-1 aircraft.

Directed and conducted human engineering studies for Army field telephone switching centers; consulted on Project Grasshopper--a jet device to be attached to a man to provide auxiliary thrust in running, jumping, etc.

Participated in studies aimed at specifying human operations at a lunar base; visual navigation for Polaris submarines; mission analyses and cockpit design for the CF-105 and XF-103 interceptors; Thor missile system; semi-automatic mail-sorting equipment; automatic airline reservation equipment and radar-ECM-data link simulation equipment.

At Frankford Arsenal, Philadelphia, Pa., 1953-1956:

Established and directed the Engineering Psychology Division and directed human engineering studies for recoilless rifles, fire control systems and equipment, the ONTOS vehicle, and cartridge-actuated devices.

ROBERT T. ECKENRODE (Continued)

Affiliations:

Ergonomics Research Society
American Ordnance Association
Scientific Research Society of America
Human Factors Society
Operations Research Society

JEROME H. ELY
Assistant Vice President

Education:

Ph.D., Purdue University, 1950

M.A., Purdue University, 1948

A.B., Southern Methodist University, 1947

General Experience:

At Dunlap and Associates, Inc., 1950 to present:

Directed or conducted human engineering and systems analyses on a variety of systems, including: combat information centers, air control centers, ground control of aircraft and missiles, communication systems, ballistic missile systems, vehicles, passive and active detection systems, data processing systems, and decision making systems to identify and evaluate threat.

Project Director for the preparation of the following chapters of the Joint Services Human Engineering Guide to Equipment Design:

Chapter V:	Layout of Workplaces
Chapter VI:	Design of Controls
Chapter VII:	Man-Machine Dynamics

Director of the Laboratory, Dunlap and Associates, Inc.

Member, Department of Defense Scientific Advisory Committee on Psychology and Social Science, subcommittee on Design and Use of Man-Machine Systems.

Affiliations:

Adjunct Professor, New York University, 1957-1959
Diplomate in Industrial Psychology, American Board of Examiners in Professional Psychology
Visiting Lecturer, Columbia University, 1953-1956
Fellow, American Psychological Association
Eastern Psychological Association
Human Factors Society

JESSE ORLANSKY
Vice President

Education:

Ph. D., Columbia University, 1940

M. A., Columbia University, 1937

B. S., City College of New York, 1935

General Experience:

At Dunlap and Associates, Inc., 1948 to present:

Directed a wide variety of military systems analyses, human engineering studies, operations research and performance evaluations. These include the following systems:

For the Army: 414A, T-33, Stinger and Skysweeper, antiaircraft defense systems; AN/MSG-5 air defense system; Army-Navy Integrated Instrumentation Program.

For the Navy: Submarine CIC, control center and communications systems; SS 563/564 attack centers; ZPN and XZP3K ASW blimps; airborne obstacle-avoidance radar; uniform control feel airplane response system; AEW and C aircraft.

For the Air Force: CF-105 cockpit development; aircraft catapult launch system; Thor missile system; advanced boost-glide vehicle; long-range interceptor; SAC Control System.

Program Director for the following chapters of the Joint Services Human Engineering Guide to Equipment Design:

Chapter I:	Methodology in the Design of Complex Man-Machine Systems (contributed parts to this chapter)
Chapter V:	Layout of Workplaces

JESSE ORLANSKY (Continued)

Chapter VI:	Design of Controls
Chapter VII:	Man-Machine Dynamics
Chapter VIII:	Arrangement of Groups of Men and Machines

Member, Air Force Scientific Advisory Board.

Consultant to Department of Defense, Office of the Assistant Secretary for Research, on Human Factors in Ballistic Missile Systems.

Affiliations:

Diplomate in Industrial Psychology, American Board of Examiners in Professional Psychology

Operations Research Society of America

SAE Committee on Lighting

ASME Technical Committee, Aviation Division

Human Factors Society

Ergonomics Research Society

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MARTIN A. TOLCOTT
Vice President

Education:

Ph.D., Columbia University, 1948

M.A., Columbia University, 1944

B.A., Columbia University, 1943

General Experience:

At Dunlap and Associates, Inc., 1948 to present:

Supervised systems and human engineering studies on Navy aircraft surface vessels and submarines, including fire control, surveillance, communications, air control, plotting and command functions, centers and stations.

Currently directs or monitors all human engineering studies for the Navy on the Polaris missile system; directed ground handling studies for five Air Force missile systems.

Formerly directed all human engineering and systems studies on Army HAWK I and Second-Generation HAWK, Navy Sparrow III.

Participated in studies on Army 414-A antiaircraft defense system, Air Force air defense system, Navy airborne early warning system, product handling for an oil refinery, plant layout for a plastics factory.

Directed a study to determine future requirements for data transmission equipment for all types of Air Force air operations.

Affiliations:

Certified Psychologist, State of Connecticut
American Psychological Association
Society of the Sigma Xi
American Management Association

JOSEPH G. WOHL
Senior Systems Engineer

Education:

B.S., University of Wisconsin, 1949
Post-graduate studies in physics, University of Maryland, 1951
Post-graduate studies in engineering administration, George Washington University, 1953

General Experience:

At Dunlap and Associates, Inc., 1957 to present:

Conducted systems analyses of the Polaris Fleet Ballistic Missile System from the human factors standpoint, including the determination of the effects of equipment design on operational readiness.

At Sperry Gyroscope Co., 1954 to 1957:

Development of studies to optimize characteristics of drone systems, drone guidance and control-display design problems; effects of operational factors on design of a radar-beacon guidance system.

At Office of Naval Research, 1952 to 1953:

Administered human engineering contracts on the Army-Navy Instrumentation Program.

Assisted in initial planning on Project Orbiter.

Established the Naval Advisory Committee on Human Engineering, and the Naval Human Engineering Bulletin.

At Naval Research Laboratory, 1948 to 1952:

Human engineering of automatic target assignment and weapon control system for cruisers, Mark 65; and for destroyers; other aircraft and shipboard weapon control and tracking systems.

JOSEPH G. WOHL (Continued)

Basic research on human information handling, tracking behavior and maintenance.

Affiliations:

Institute of Radio Engineers
Scientific Research Society of America
Lecturer in Systems Engineering, Columbia University, 1958 to present